

EXPERIMENTAL TECHNIQUES IN HOLOGRAPHIC
INTERFEROMETRY

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EXPERIMENTAL TECHNIQUES IN
HOLOGRAPHIC INTERFEROMETRY

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Experimental Techniques In
Holographic Interferometry

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ABSTRACT

Fiber light guides are used in conjunction with holographic interferometry. A Michelson interferometer was constructed to test for temporal coherence of light passing through fiber optics. A finite-fringe hologram of a no-flow condition was taken to prove the feasibility of applying fiber optics to this field of flow investigation.

The effect of opaque bodies on interferometric data inversion was sought. Two schemes for replacing the missing fringe data were used to see if the accuracy of the calculated density fields could be enhanced.

II. THEORETICAL INVESTIGATION OF LIMITED FIELD OF VIEW	12
A. INTRODUCTION	13
B. PROCEDURES	16
C. RESULTS	18
1. Centered Function	19
2. Displaced Function	20
3. General Trends	20
III. CONCLUSIONS AND RECOMMENDATIONS	22
FIGURES	24
MAIN COMPUTER PROGRAM	32
SUBPROGRAM OF INTPL	79
SUBPROGRAM OF INTPL (LINEAR)	80
LIST OF REFERENCES	84
INITIAL DISTRIBUTION LIST	87
FORM 88 1-73	91

TABLE OF CONTENTS

I.	EXPERIMENTAL WORK ON FIBER OPTICS -----	4
A.	INTRODUCTION -----	4
B.	EXPERIMENT -----	7
	1. Equipment -----	7
	2. Michelson Interferometer -----	8
	3. Holographic Arrangement -----	9
	4. Testing Procedure -----	11
C.	RESULTS -----	12
	1. Michelson Interferometer -----	12
	2. Holographic Experiment -----	13
II.	THEORETICAL INVESTIGATION OF LIMITED FIELDS OF VIEW -----	15
A.	INTRODUCTION -----	15
B.	PROCEDURE -----	16
C.	RESULTS -----	18
	1. Centered Function -----	19
	2. Displaced Function -----	20
	3. General Trends -----	20
III.	CONCLUSIONS AND RECOMMENDATIONS -----	22
	FIGURES -----	24
	MAIN COMPUTER PROGRAM -----	33
	SUBPROGRAM OF INTRPL -----	79
	SUBPROGRAM OF INTRPL (LINEAR) -----	80
	LIST OF REFERENCES -----	89
	INITIAL DISTRIBUTION LIST -----	90
	FORM DD 1473 -----	91

I. EXPERIMENTAL WORK ON FIBER OPTICS

A. INTRODUCTION

Holographic interferometry is an invaluable and frequently used tool in modern flow field visualization. Numerous articles have reported on the application of holography to interferometry, among the first of which was presented by Heflinger, et al. [Ref. 1]. The history, the theory, and diverse applications of holography are presented in Collier [Ref. 2]. Holographic application to interferometry has been extensively investigated for pure gas flows [Ref. 3], for flows around transparent bodies [Ref. 4], and for flows around opaque bodies [Ref. 5].

The principles of holography have been known since 1947 when Gabor developed the principle as an improvement for electron microscopy [Ref. 2], but the current scientific applications awaited the development of a coherent visual radiation source. Previously, flow field visualization relied on interferometric techniques utilizing light sources of poor temporal coherence.

The specialized area of interferometric holography includes such techniques as real-time, time-averaging, stroboscopic, and time-lapse. They are discussed in Ref. 6. The time-lapse technique, also referred to as double exposure, is used for flow field visualization. This technique involves superimposing the phase and amplitude information of a flow condition upon that of a no-flow

condition. An improvement to time-lapse holography was achieved by the use of diffusing screens positioned in the scene beam. The idea was advanced by Heflinger [Ref. 1], while Gates further developed the concept [Ref. 7]. In normal side-band holography, each point on the object acts as a diffusely reflecting light source. Light reflected from all points on the object can mutually interfere with light from all other points. The total interference pattern produces a three-dimensional image. This three-dimensionality can be obtained in holographic interferograms of transparent objects by introducing a diffusing glass plate in the scene beam just prior to the test section.

Two varieties of time-lapse holography are the infinite fringe and the finite fringe methods. Infinite fringe patterns occur when the wave fronts of the separate exposures see exactly the same optical arrangement. Finite fringe patterns occur when a finite displacement is introduced in the optical arrangement between exposures. The fringe for the undisturbed region are parallel, equispaced lines which will be perpendicular to the direction of translation. These parallel, equispaced lines form a convenient scale for determining the fringe shift values in the disturbed region of flow.

The double exposure has the advantage of relaxing the tolerances of the optical equipment. Both flow and no-flow beams travel common optical paths which effectively eliminates the interference fringes from optical imperfections

of the experimental apparatus. This phenomenon is such that good quality holograms can be constructed with extremely rudimentary setups and optical components.

One final improvement in technique was required for the true versatility of holographic interferometry to emerge. Mechanical stability of the experimental components was required to achieve proper fringe interference patterns. The stability needed to be on an order of the wavelength of the light being used. The pulsed laser has eliminated stability problems during exposures by its ability to "freeze" the flow through exposure times in the tens of nanoseconds. Inherent in the pulsed laser is a loss of coherency length as compared to the continuous-wave laser (c.w. laser). Coherency lengths are strongly dependent on the number of modes that can oscillate simultaneously. For pulsed lasers, coherency lengths are normally on the order of tens of centimeters.

There is a need to relax the typical experimental arrangement to further expand the versatility of holographic interferometry. Data for flow field visualization must normally be collected from wind tunnel tests which only simulate real life. Freedom from the laboratory environment could be achieved by adapting fiber light guides to channel coherent light to and from real-life flows. Interferometric data could thus be collected on many interior flows or hazardous flows which do not lend themselves to standard experimental setups. Real-life flows such as inlet flows

or compressor flows could be investigated. To determine the feasibility of applying fiber optics in this fashion, a basic interferometric experiment was conducted using a fiber light guide to transmit a portion of the laser beam to the photographic emulsion.

B. EXPERIMENT

1. Equipment

The initial endeavor to achieve holograms using fiber optics was made with a 15 m.w. continuous wave helium-neon laser. Having found this inadequate, a Korad K-1 pulsed ruby laser with a Pockels cell Q-switching device was used in its place. The laser operates at a wavelength of 6943 Angstroms and has an effective exposure time of 20 nanoseconds. The fiber optics employed were 1/4-inch bundles, one being twelve inches in length and the other 24 inches. The c.w. laser was used for alignment of the pulsed laser beam through all the optical components. Also, the c.w. laser was used to establish the relative intensities of the scene and reference beams. Optical components consisted of several concave lenses, a beam splitter which was 20% reflective, front surface mirrors, and diffusing glasses of several different densities. A precision X-Y translating stage was used to achieve finite fringe lines. A schematic of the experimental arrangement is shown in Figure 1. Because the experiment was to be a double-exposure hologram, the quality of the optical

components was not of concern. An optical bench for isolating extraneous vibrations from the experiment was also deemed unnecessary due to the high speed exposures being used. The photographic emulsions used were AGFA-GEVAERT 10E75 holographic plates.

2. Michelson Interferometer

A Michelson interferometer [Refs. 2, 6, and 8] was constructed to make an initial start in determining the feasibility and the associated problems of holography employing fiber optics. One path length of the interferometer was replaced by a fiber light guide. [Fig. 2] The refractive index for the optic bundle was taken as 1.5 and an appropriate compensation was made in the optic path lengths. The interferometer is a test for temporal coherence of light. Temporal coherence for laser sources of light is extremely good and is the basic quality allowing for the development of the modern expansion of holography. When the paths are exactly matched, a well-defined circular interference pattern should be visible on the screen. If one path length is changed (ΔL) the fringe pattern becomes less distinct. The point at which the fringe could be considered no longer existent is a subjective quality and the value of $2\Delta L$ at this arbitrarily accepted visibility of the fringe lines defines the temporal coherence length of the laser. Pulsed lasers have coherence lengths on the order of 10 to 20 cm.

3. Holographic Arrangement

The holographic arrangement is illustrated in Figure 1. The pulsed laser was mounted on an optical rail along one side of the work table. In its path a removable front surface mirror was positioned which directed the alignment laser along the identical path as the pulsed laser. The high intensity pulse was spread by a concave lens to prevent the high intensity beam from scoring either the beam splitter or the fiber optics. The beam splitter was 20% reflective allowing the greater amount of energy to enter the fiber optics. It was necessary to direct a high percentage of the energy into the fibers for there is a 43% internal optical loss associated with the 24 inch length. Also, the divergence of the beam leaving the fibers is sufficient to cause a rapid loss in beam intensity as the free-air path length of the beam is increased. The reflected beam was used as the reference beam. It was directed to a front surface mirror and through two concave lenses to the photographic surface. The other portion of the beam entered the fiber bundle after passing through the beam splitter and was then directed to the photographic plate. Both beams had a 30° incidence angle to the normal of the photographic plate. A precision X-Y translation stage was used in the scene beam. It was initially used to translate the fiber ends and later to translate a diffusing plate placed in the scene beam.

Alignment and the relative intensities of the scene and reference beams were achieved with the c.w. laser. Alignment was achieved in the following manner. At two points 0.5 meters apart along the optical, rail blackened photographic papers were positioned. These were burned with the pulsed laser using a 1.5 mm. aperture. Pin holes were made in the center of each spot. A removable mirror was placed on the rail which reflected the c.w. laser beam through the two pin holes. This beam was a visual equivalent of the invisible pulsed laser beam and could be readily aimed through the optical components. Each beam was centered on a target grid set in the photographic plate holder.

The loss of intensity through the fiber optics was not a controllable factor and as such, all adjustments for the relative intensity of the two beams were made to the reference beam. Two concave lenses closely spaced gave the needed control of the divergence of this beam. White sheets of paper were held in front of each beam and a visual estimation of the intensities was made. It was attempted to have the reference beam from two to three times as intense as the scene beam.

The equivalent free-air path lengths for both beams was approximately 190 cm. The free air portion of the scene beam, that portion from the exit of the fiber optics to the photographic plate, was determined by two factors;

having the fibers far enough away to achieve maximum coverage of the photographic plate, and not being so far as to seriously diminish the intensity of the beam.

4. Testing Procedure

To initiate testing, all alignment devices were removed and a 2.5 mm. aperture was placed in the transverse mode selector. It proved prudent to make an additional test for correct alignment and relative intensities before proceeding with the actual experiment. This was accomplished by making two initial exposures, allowing only one beam at a time to expose each of two different plates. After developing these plates, a more reliable visual comparison could be made of the two beam intensities. This also gave assurance that both beams were sufficiently centered on the photographic plate.

To prove the feasibility of holographic interferometry employing fiber optics, an initial step was to achieve finite fringe lines of a no-flow condition. Since the fibers consist of a large number of independent light sources, each one emanating from the end of each individual fiber, it was felt at first that this property of the light guide would obviate the need for a diffusing plate in the scene beam as is customarily used. As such, the fiber bundle was attached to the X-Y translation stage. Between exposures the stage was translated 0.003 inches horizontally to produce vertical fringe lines. Additionally, the experiment was performed

using a diffusing plate translated in the same manner, in place of translation of the fiber optics.

C. RESULTS

1. Michelson Interferometer

The Michelson interferometric experiment produced positive results. A fringe pattern was observed on the screen from the interferometer employing the fiber light guide. The temporal coherence was preserved through the fiber optics. It became evident that the experiment was highly sensitive to vibration. This portion of work was accomplished on a vibration isolating optical bench. When the experiment was initially performed without fiber optics, the fringe pattern would waver whenever slight shocks were induced in the concrete floor of the test room. Once the fibers were positioned, the sensitivity to vibration was greatly heightened. The fringe pattern was observed only after extensive and minute adjustments were made to the optical components. The fringe pattern was seen for but an instant. Because of the difficulty of stabilizing the optical arrangement, no further investigation was made to determine whether there was a degradation of coherency length by the fiber optics. The apparent increased sensitivity to vibration of the fringe formation necessitated using high-speed exposures achieved with a pulsed laser for all further work.

2. Holographic Experiment

The first phase in the experiment sought to ascertain the need for a diffusing plate. In view of the large number of individual fibers contained in the light guide, would each fiber act as an individual light source and produce a similar effect to that of a diffusing plate? Initial holograms were made of a transparent phase object, a rhombohedral plastic form, as well as finite fringe lines. The technique proved unsuccessful. Finite fringe lines were not produced. However, a hologram of the phase object was achieved. It was of poor quality and contained only a picture of the light emitted by the fibers and several high-intensity reflections of light from the inner walls of the rhombohedron. The appearance was exactly that of previous holograms attempted where a diffusing plate was not incorporated.

Further testing was limited to achieving a finite fringe pattern using the diffusing plate attached to the translating stage. Vertical fringe lines of a no-flow condition were achieved. The fringe lines were clearly visible, but were confined to only a portion of the photographic plate.

During the alignment portion of the experiment, it was noted that the uniformity of the beam from the fiber optics was greatly influenced by the positioning of the incidence beam. The most uniform pattern was achieved by an incident beam covering approximately one third of the

area of the fiber ends. This result was enhanced if the beam was directed off center. Minute changes in its position on the fiber ends greatly influenced the quality and focus of the emitting beam. Since the pulsed beam is unobserved, no positive control of the beam from the fibers was assured. It would be reasonable to suspect this uncertainty for the number of failures and the eventual poor quality of the holograms achieved.

II. THEORETICAL INVESTIGATION OF LIMITED FIELDS OF VIEW IN HOLOGRAPHIC INTERFEROMETRY

A. INTRODUCTION

An attempt was made to further investigate the problem of data reduction for supersonic flows containing opaque bodies. An initial effort toward this was presented by Jagota and Collins [Ref. 5]. Known values of density along various lines of sight were obtained from AGARD [Ref. 9] for a specific cross section in the flow about a cone. To diminish the effect of the presence of the cone in the flow, a fictitious constant density distribution equal in value to the density at the cone surface was added. The new density field, which now covered the entire test section area, was used to calculate a fringe number array that would have resulted from such a density distribution. These data were then reinverted to obtain a density distribution which was compared to the original density. Reference 8 contains the computer program used for the data reduction.

Further research into flow around opaque bodies has been facilitated by the development of an alternate computer program using a Fourier transform method in place of the Fourier expansion used in Ref. 8 to solve the pertinent equations. Van Houten discussed this method in Ref. 10. The main advantages of the program are in the computational time required and the numerous options available to the user.

Computational times on the order of two minutes made the program by Van Houten ideally suited for exploring different schemes to calculate the density field around an opaque object.

B. PROCEDURE

Because one would normally be starting with experimentally observed fringe data, manipulation of this information was chosen as a starting point instead of the density field change used in Ref. 5. A fictitious density distribution was formulated corresponding to Fig. 8 of Ref. 10. The relative refractive index function was given by:

$$\begin{aligned} f(X,Y) &= (1 - Y^2) e^{-2x^2} & R \leq 1.5 \\ &= 0 & R > 1.5 \end{aligned} \quad \text{eq. (1)}$$
$$R = X^2 + Y^2$$

The computer program used this input to calculate a refractive index field over a 4 in. by 4 in. cross-sectional area. The field was calculated at 101 equispaced points on both the X and Y axes. Mode 1 of the program starts with the relative refractive index function, calculates an initial refractive index field at selected points from this, computes the fringe shift that would be observed from the field, and recalculates a new refractive index field from the fringe shift information. These calculations were used as standards against which other flow fields were to be compared.

Two experimental phases were studied; Van Houten's Fig. 8 was centered within the test field, and the same figure was translated 0.25 in. along both axes. The KSYM argument of the computer program, which is a measure of symmetry of the field about the origin, changed between cases. The translation destroyed the symmetry found along both axes in the original figure.

Mode III of the program uses fringe information supplied as data, and from it calculates a refractive index field. To simulate the presence of an opaque body immersed in the flow, fringe information obtained from Mode I was blocked over a portion of the field. The blocked portion was the center portion of the flow field. This portion of the fringe data blocked by the presumed body was restored using two numeric schemes. The reconstructed fringe shift information was used to recalculate the refractive index field. This allowed for a direct comparison between density distributions of the free flow with that of a flow around the opaque body.

The program from Ref. 10 was modified for this use and is presented in Appendix A. Two schemes were used for reconstructing the lost fringe information. The first method used a U. S. Naval Postgraduate School Computer Library subroutine titled INTRPL. This was incorporated in a subprogram [Appendix B] that read in the entire fringe shift information and automatically destroyed the middle quarter of the data. INTRPL used the remaining field to

recalculate the missing portion. The second scheme [Appendix B] filled the same missing information with a linear interpolation. The two newly constructed fringe number arrays were reinserted in the main computer program under Mode III and the resulting refractive index fields were obtained.

C. RESULTS

Six separate computer runs were made, the first three dealing with the function centered on the X- and Y-axes, and the last three dealing with the displaced function. Each group of three runs commenced with a given refractive index function from which was calculated the refractive index field at selected grid points using the Mode 1 operation. All subsequent runs were done under Mode 3. The second run of each group used the fringe shift array as modified by the INTRPL subprogram. The third run used the same information as modified by the linear interpolation subprogram. A diagram of the calculating procedure is given in Figure 3.

Contour plots of all refractive index fields were used to compare results for the different cases. Contour lines were produced at 0.1 intervals from the maximum function value of 1.0 to the minimum value. Comparisons among the contour plots were made using two different criteria; errors of the test case values from the values of the standard case in percent of the maximum value of the function, and the number of calculation grid points between

equal contour levels of each graph. Comparisons were terminated at the boundary of the simulated body. The body consisted of a circular region of a 0.5 in. radius located at the center of the cross-sectional area.

1. Centered Function

Figure 4 presents the refractive index field calculated by Mode 1 using the density function given in Equation 1. This is the standard of comparison for the other centered cases. In Fig. 5, the center portion of the fringe array has been removed and replaced by the subroutine INTRPL. In Fig. 6, the center portion of the function has been removed and replaced by a linear interpolation.

The greatest error encountered in comparing the standard, Fig. 4, with Fig. 5 was at the surface of the body. This error was on the order of 8%. Errors around most of the body were approximately 5%. Elsewhere in the flow, the maximum error observed was 2.5%. Generally, the lower-valued contour levels away from the body were very closely matched.

A comparison of Fig. 4 and Fig. 6 produced greater errors. The contour lines developed sinusoidal-like oscillations over the entire flow field. For comparing these irregular contour levels a mean value between peaks in the oscillation was estimated and compared with the standard case. Again, the greatest error was found at the body surface. There was a 10% error in the positive Y-direction

that diminished rapidly around the rest of the body. Errors away from the body were negligible along the Y-axis, but were 6% along the X-axis.

2. Displaced Function

Figure 7, calculated in the same manner as Fig. 3, is the standard of comparison for the displaced cases. In Fig. 8 and Fig. 9, the center portions of the fringe array were, as before, with the centered functions, replaced by INTRPL and by the linear interpolation, respectively.

A comparison of Fig. 7 with Fig. 8 showed slightly increasing errors over those of the centered cases. The greatest error occurred again where contour levels intersected the body. Errors in this region were from 7% to 12%, the higher error being associated with the higher contour levels. Elsewhere, there was good agreement between the two figures with the maximum error being on the order of 4%.

Figure 9 again produced sinusoidal-like oscillations. Using the same procedure discussed for Fig. 6, the maximum error was found to be about 5%. Again, as the contour lines neared the body, accuracy was lost. Errors had improved slightly in this region over the last comparison and were from 7% to 10%.

3. General Trends

Errors for the centered functions were found to be concentrated along the X-axis. Errors for the displaced functions were generally found in quadrant III. Flow fields

for both functions showed little error along the Y-axis. It should be noted that the Y-axis contained a discontinuity and a region of negative values.

The second method used to compare flows determined the number of grid points between like values of contrasted flows. The accuracy in the general location of contours from figure to figure was considered good. Contours locations differed by no more than two grid points.

III. CONCLUSIONS AND RECOMMENDATIONS

It has been demonstrated that fiber light guides can be applied to holographic interferometry. The experiment was rudimentary and requires refinement. The problems encountered in the course of the experiment involved accurate alignment of the pulsed laser beam and attenuation of energy associated with the fiber optics.

If more realistic experiments are to be conducted, longer fibers will possibly have to be used. Transmission losses of the order of 65% are associated with six-foot lengths of fibers. A means of coping with this high magnitude loss is needed.

The incomplete fringe information associated with the limited fields of view caused by an opaque body positioned in a flow field was tested using two methods of calculating data values for the blocked portion of the fringe array. Both methods provided fair estimates of the flows in the region near the surface of the body, but there was a general degradation of flow information over the entire flow region producing errors on the order of 5% to 10%.

In using the Fourier transformation method for fringe conversion given in Ref. 10, there is a degradation to the flow field due to the finite spacing of the grid points. This effect has not fully been investigated. Errors associated with the two schemes for creating fringe data

for blocked portions of the flow can compound the inherent errors of the basic program.

Further endeavors could be made in determining the effect on the investigation caused by differing the percentage of view that is blocked. The program could be run using a finer grid pattern or a greater number of views. These factors could all have an effect on flow errors.

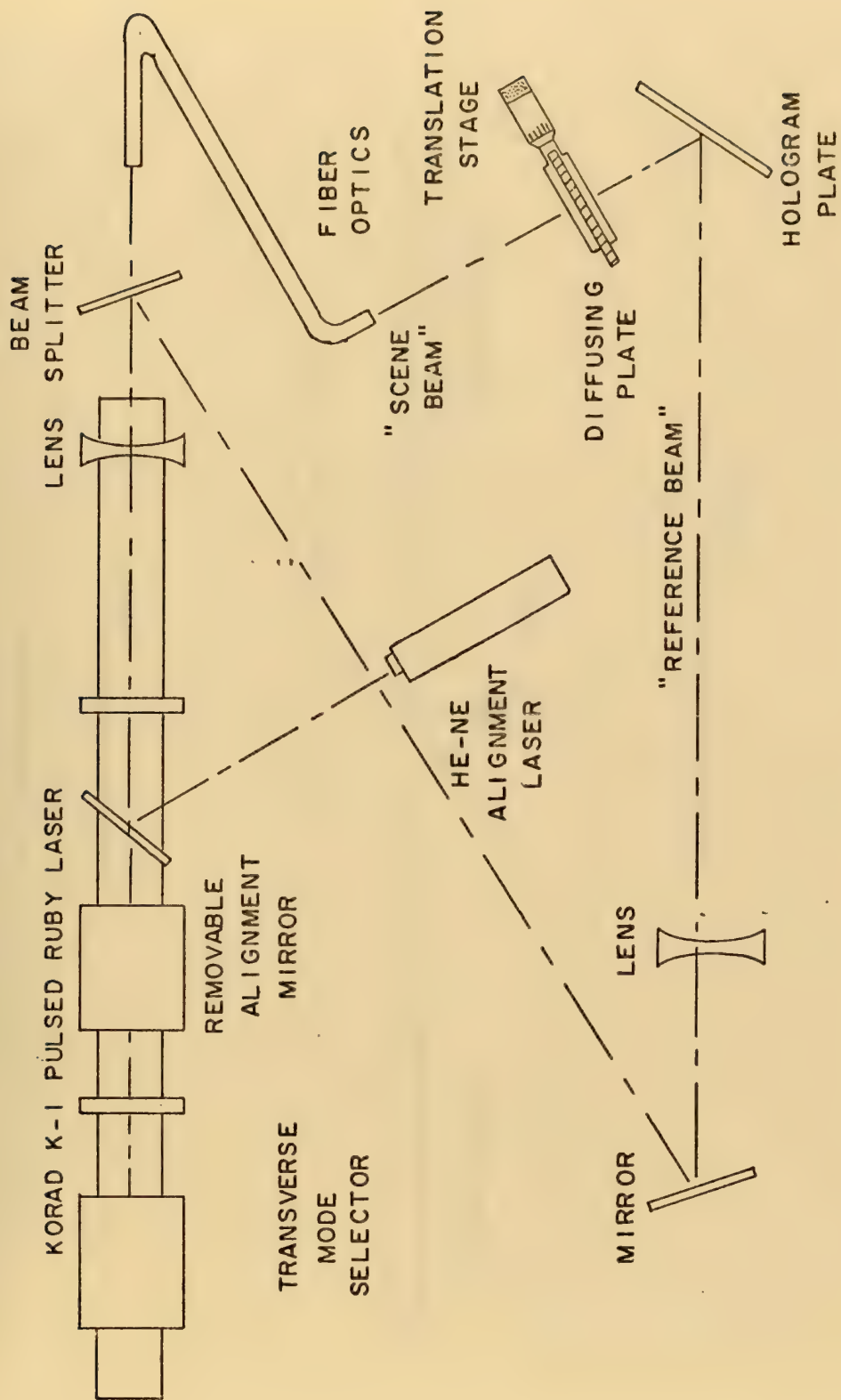


FIGURE 1. SCHEMATIC DRAWING OF THE HOLOGRAPHIC ARRANGEMENT

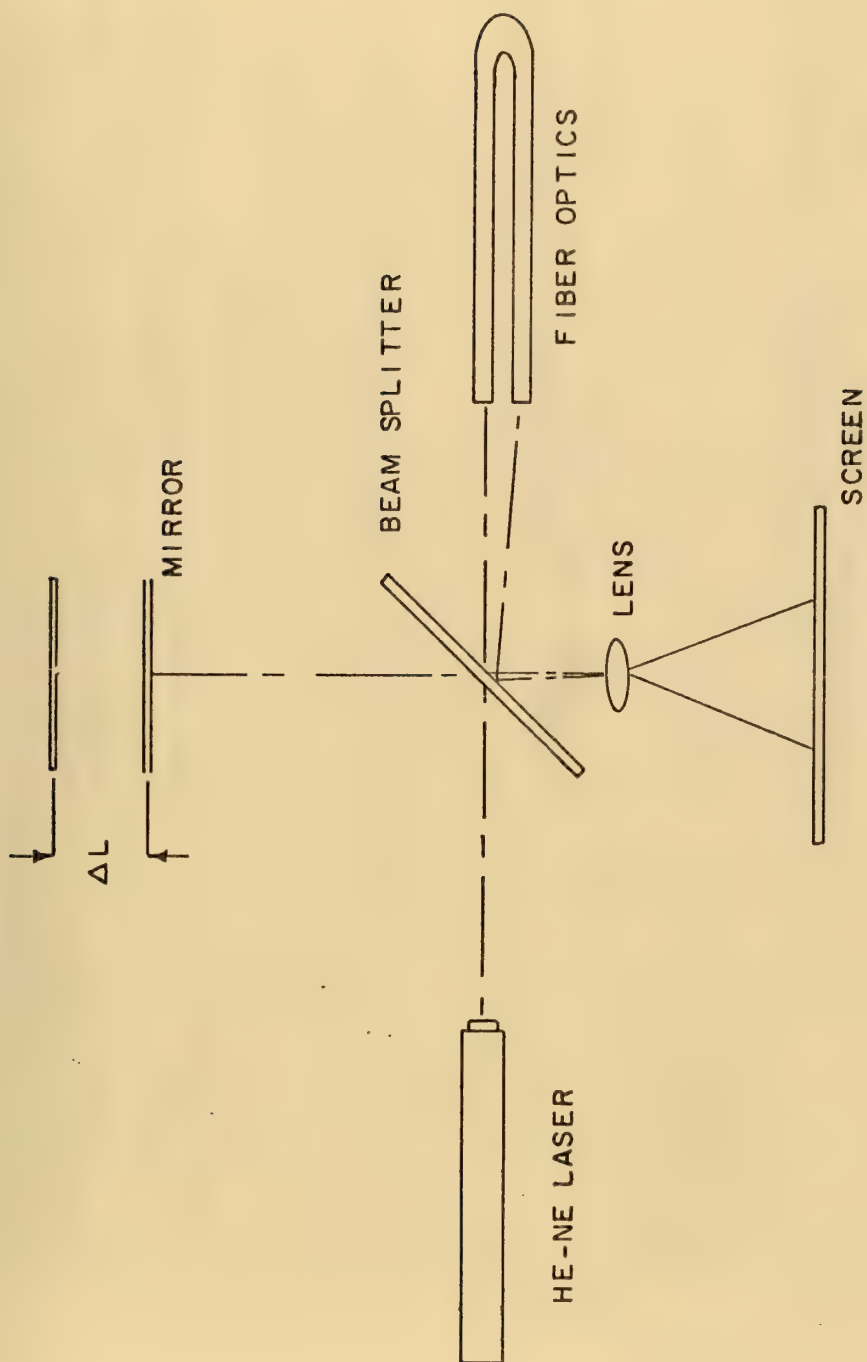


FIGURE 2. MICHELSON INTERFEROMETER WITH FIBER OPTICS

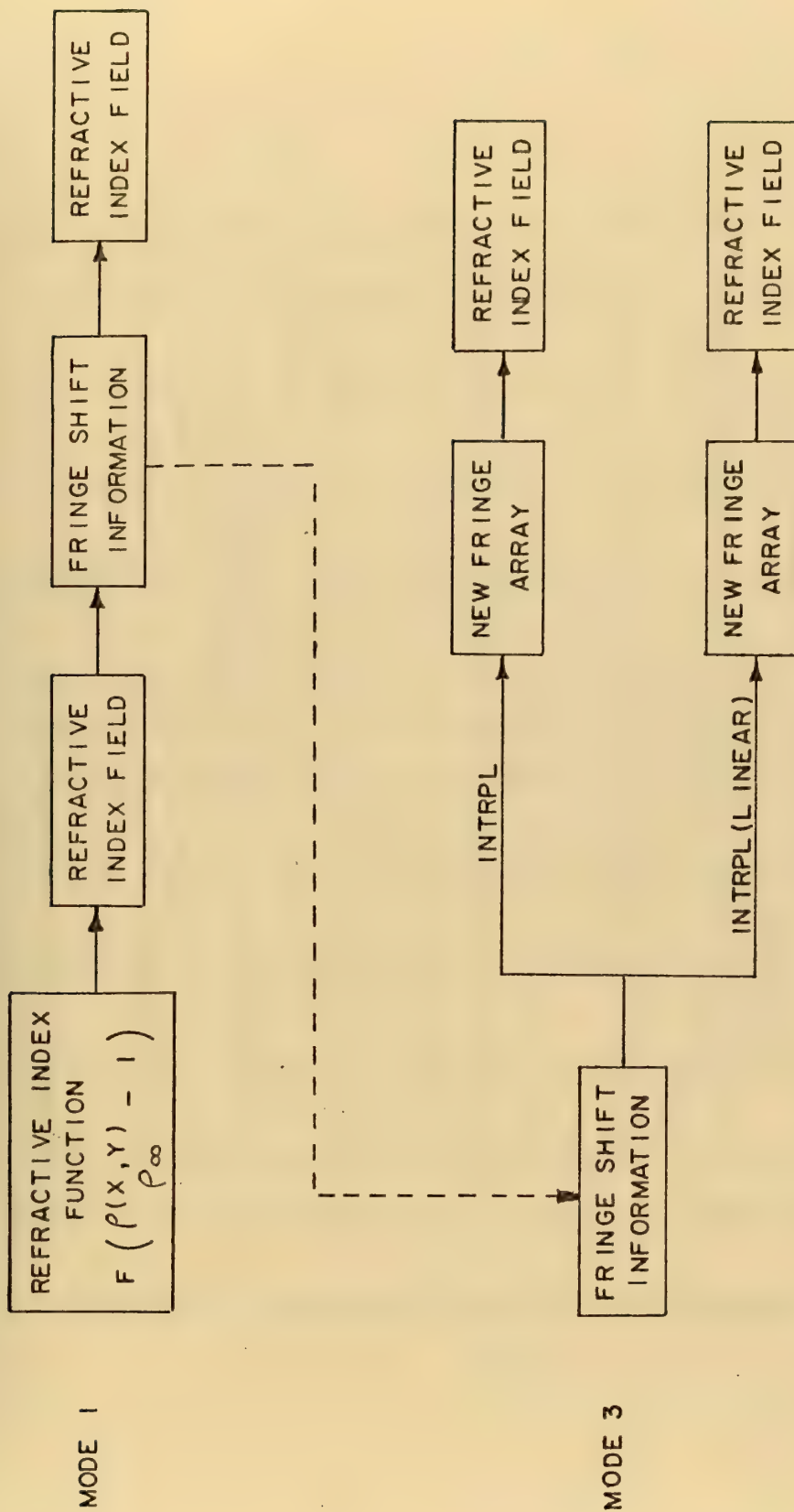


FIGURE 3. CALCULATION FLOW DIAGRAM

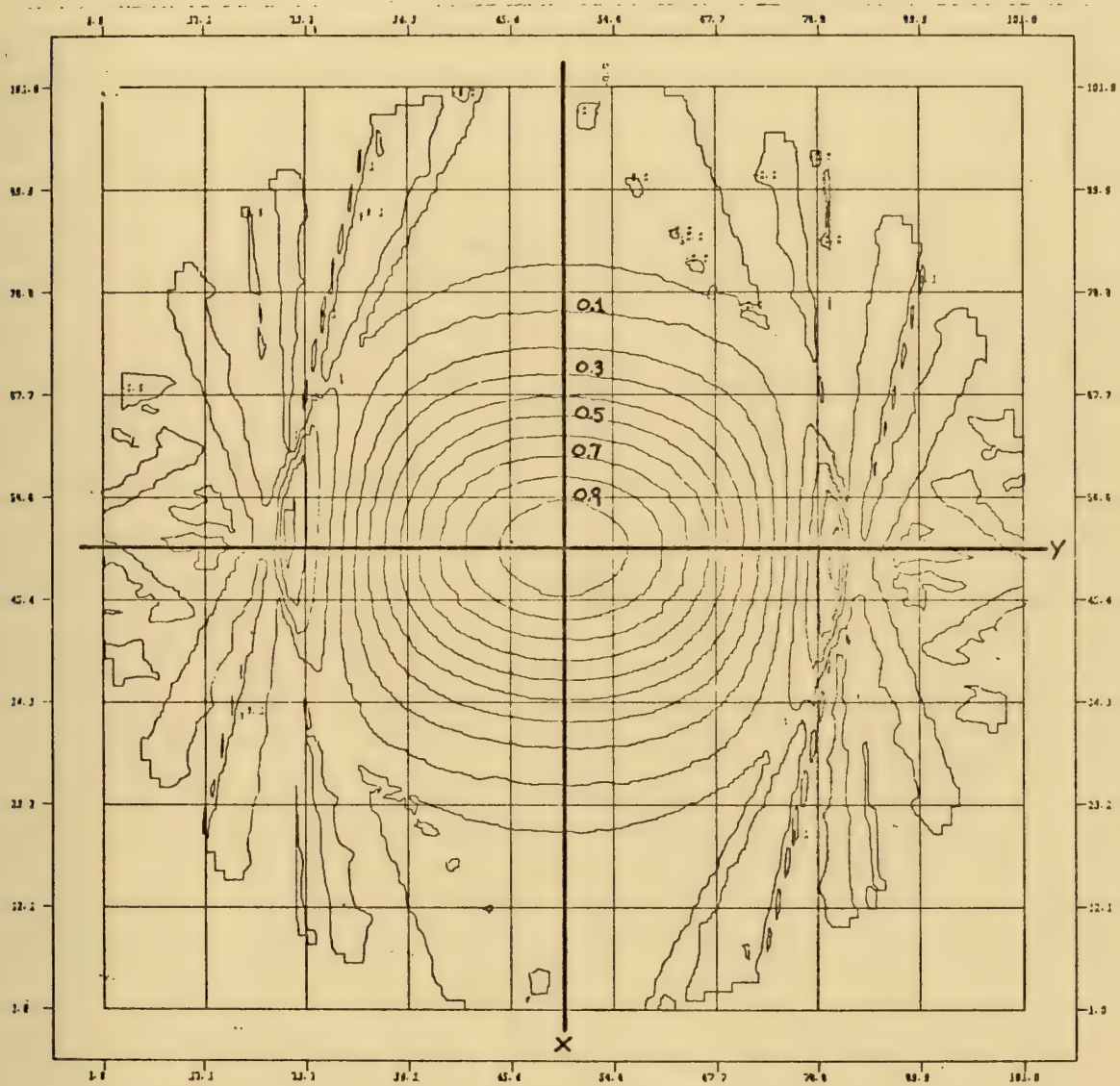


Figure 4. Standard Case for the Centered Function

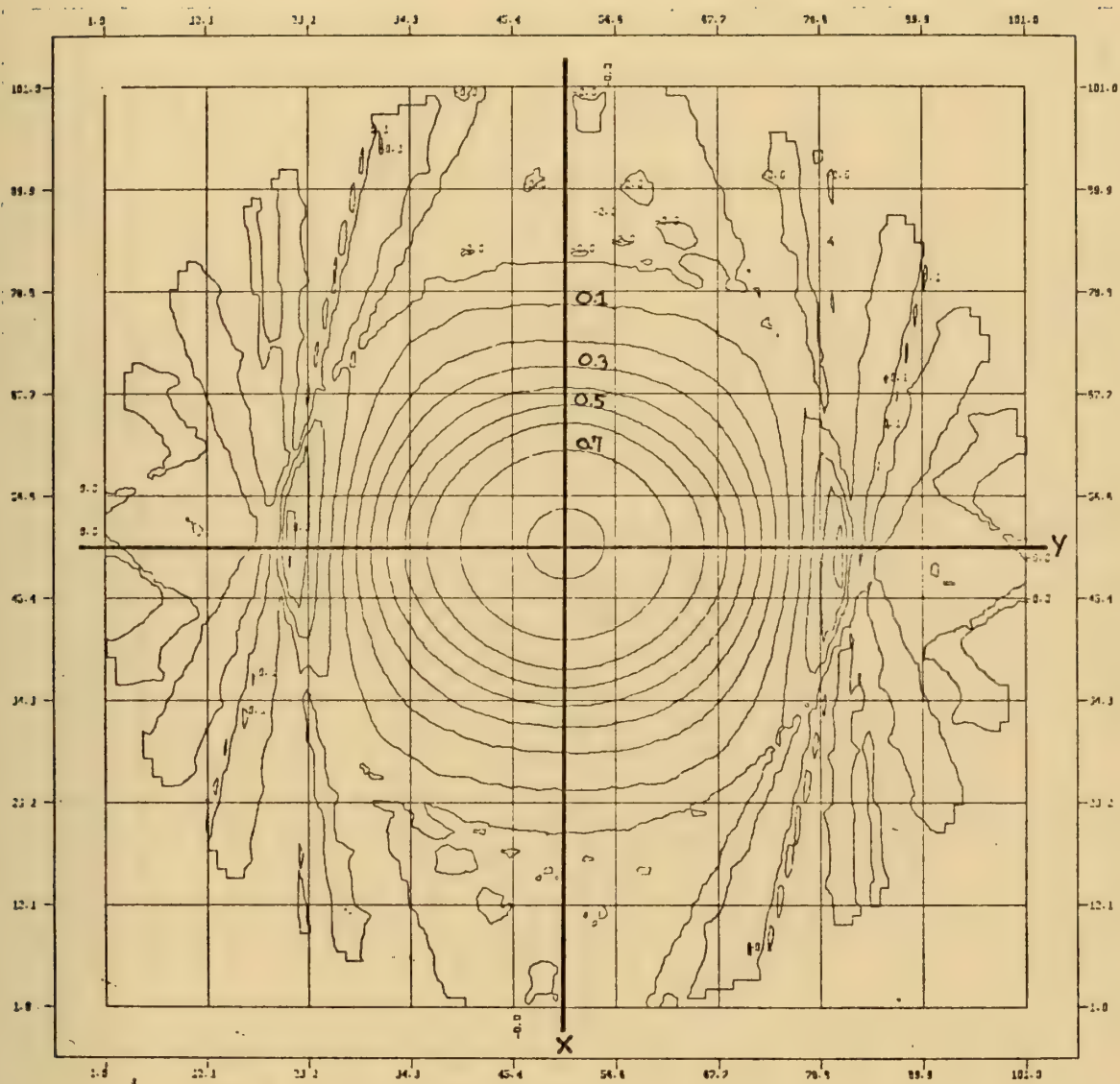


Figure 5. Centered Function Modified by INTRPL

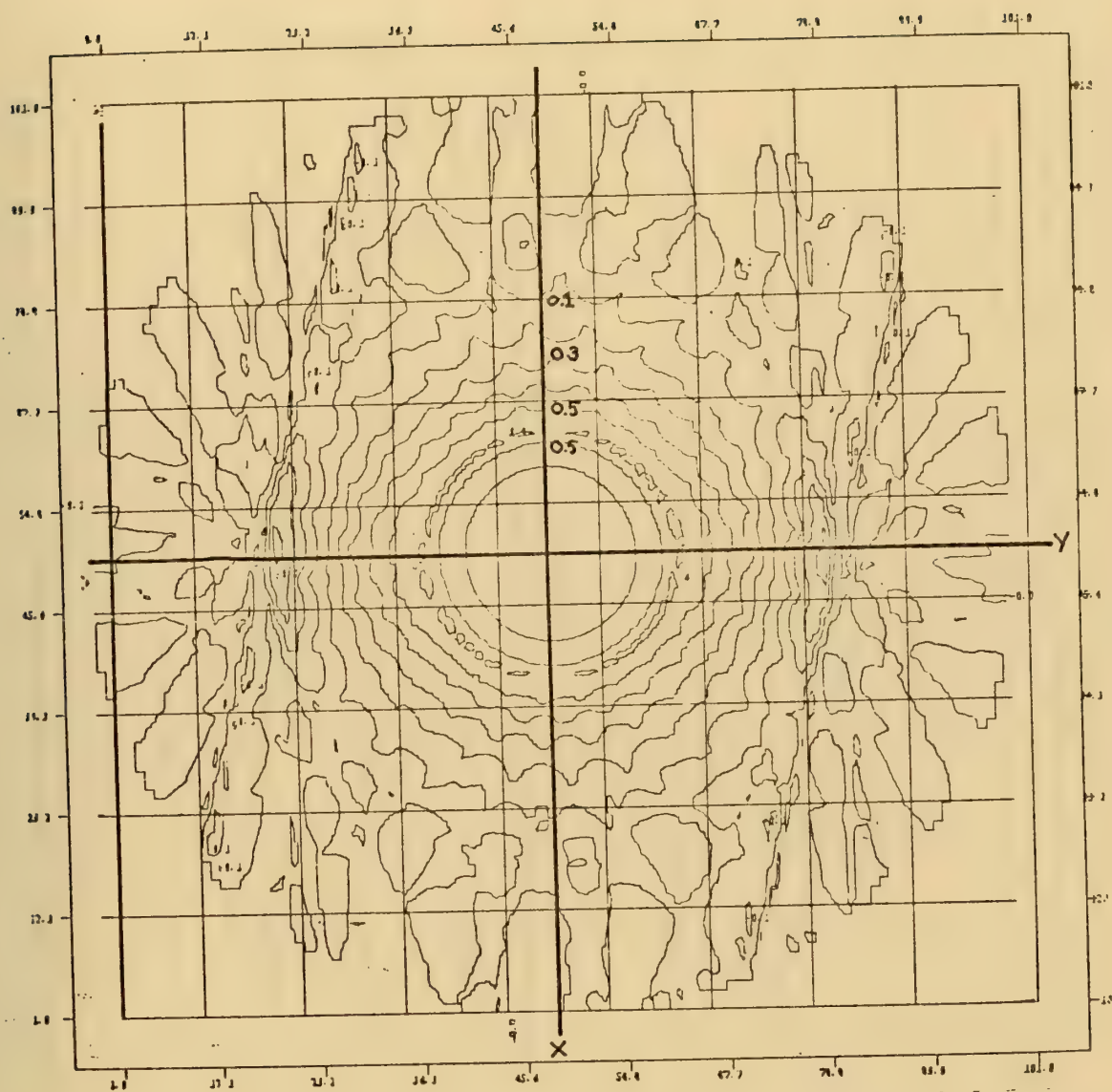


Figure 6. Centered Function Modified by INTRPL (LINEAR)

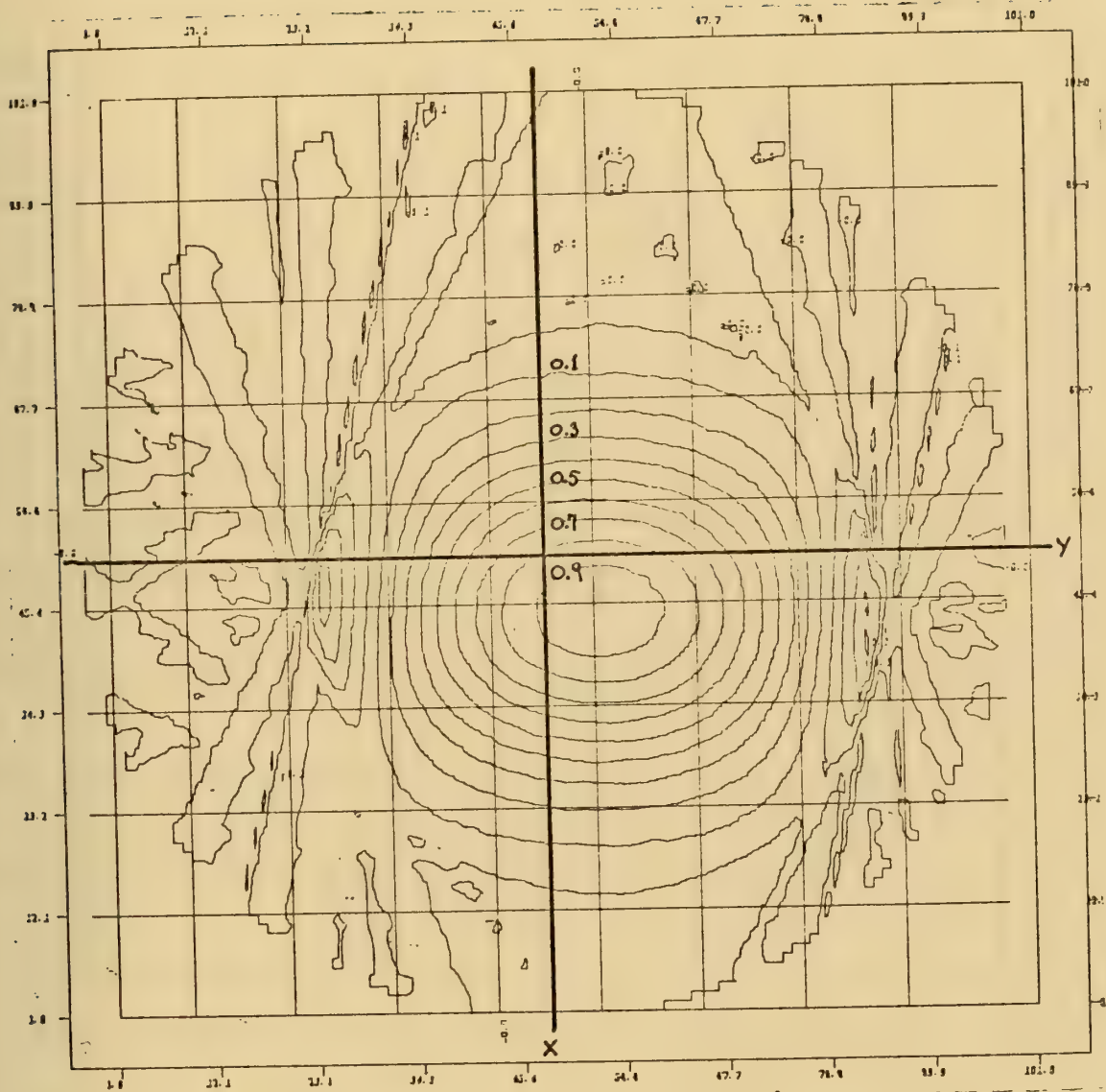


Figure 7. Standard Case for the Displaced Function

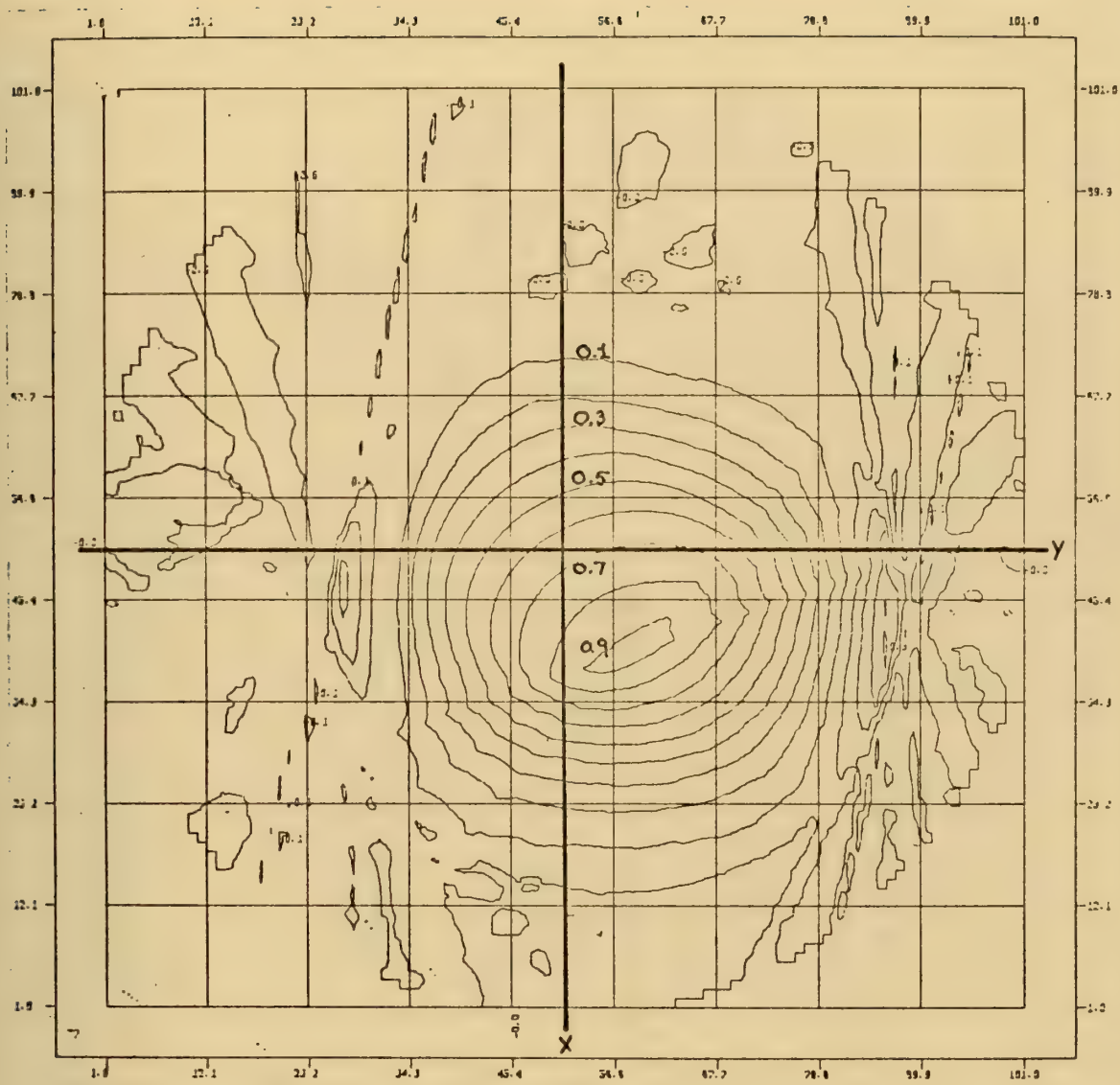


Figure 8. Displaced Function Modified by INTRPL

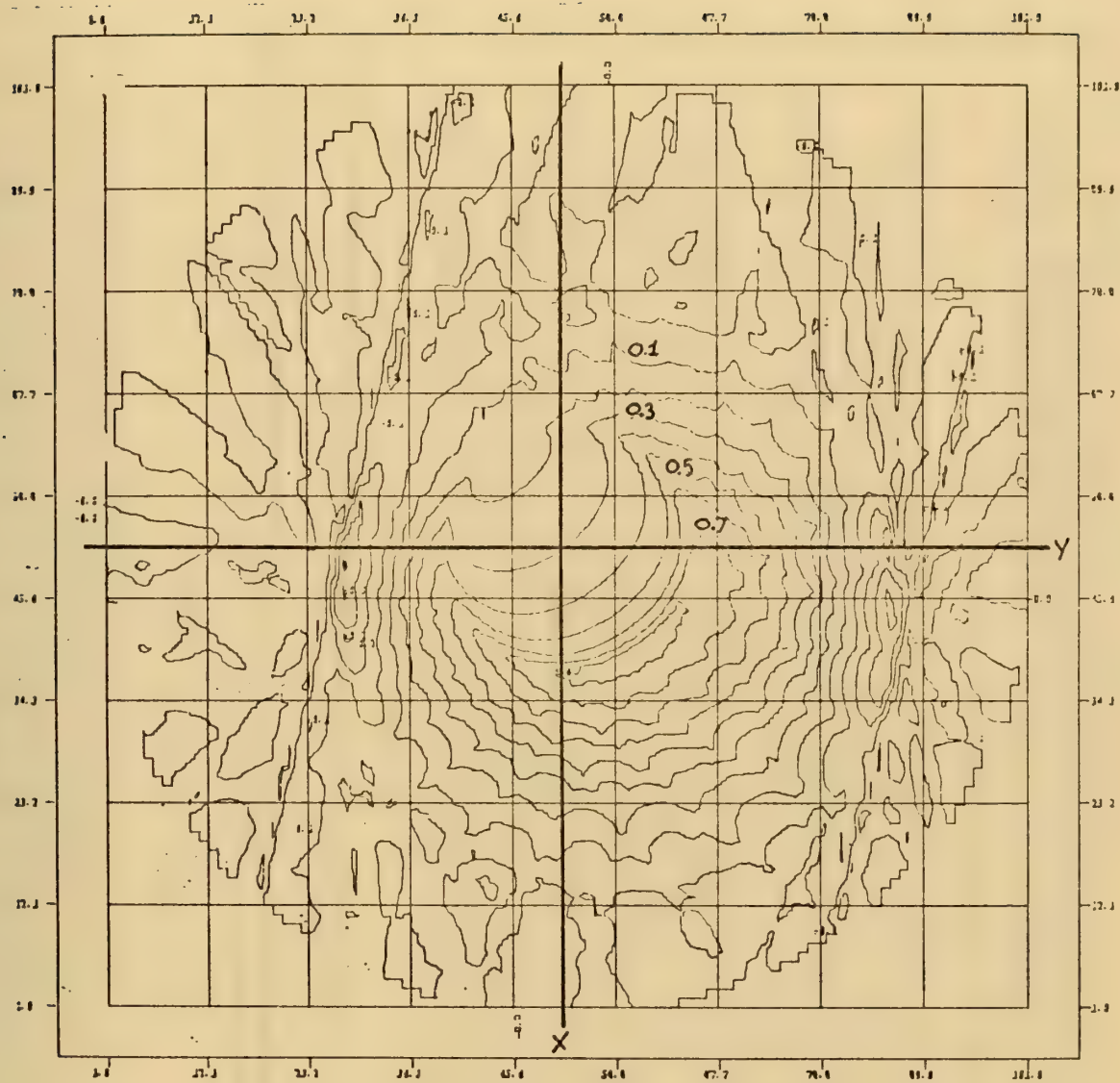


Figure 9. Displaced Function Modified by INTRPL (LINEAR)

APPENDIX A

MAIN COMPUTER PROGRAM

INTEGRAL INVERSION

REFERENCE, THESIS BY P. E. VAN HOUTEN, THE APPLICATION OF HOLOGRAPHIC INTERFEROMETRY DENSITY FIELD, 14 DEC 72
 TINUOUS THREE-DIMENSIONAL DENSITY FIELD, 14 DEC 72
 THE PROGRAM CONSIDERS A CIRCULAR REGION OF UNKNOWN LENGTH
 REFRACTIVE INDEX FOR WHICH THE TOTAL PHASE SHIFT (PATH LENGTH
 DIFFERENCE) IS KNOWN FOR NUMEROUS RAYS AT REGULAR INTERVALS
 FOR A GIVEN VIEWING ANGLE. THE PROGRAM REQUIRES NUMEROUS
 VIEWS AT REGULARLY SPACED INTERVALS AND A TOTAL ANGULAR
 COVERAGE OF 180 DEGREES (ASYMMETRIC). THE NECESSARY ANGULAR
 COVERAGE IS REDUCED BY THE NUMBER OF DEGREES OF SYMMETRY.
 BY THE USE OF TWO DIMENSIONAL FOURIER TRANSFORM TECHNIQUES
 IT CAN BE SHOWN THAT FOR A GIVEN POINT (XO, YO) WITHIN THE
 CIRCULAR REGION, THE DENSITY INFORMATION CAN BE EXPRESSED IN
 TERMS OF THE PHASE SHIFT INFORMATION $G(R, \theta)$.
 IN ORDER TO SAVE COMPUTATION TIME, THE VALUE OF THE EACH
 INSIDE INTEGRATION IS COMPUTED AT EACH RAY POSITION FOR EACH
 VIEWING ANGLE. FOR A GIVEN POINT (XO, YO), THE VALUE OF THE
 INSIDE INTEGRAL IS DETERMINED BY AVERAGING OVER A FINITE
 PORTION OF A CUBIC POLYNOMIAL FITTED TO THE FOUR CLOSEST
 VALUES OF THE INSIDE INTEGRAL. THE INTEGRATION OVER θ USES
 COTES TRAPEZOIDAL RULE. THE INTEGRATION OVER R USES
 COTES SIXTH ORDER QUADATURE FORMULA

MEANING OF SYMBOLS USED IN THE PROGRAM

IT(12) TITLE USED FOR OUTPUT. FIRST 48 CHARACTERS ON FIRST
 DATA CARD, FIRST 16 CHARACTERS ON NEXT DATA CARD
 RHOINF-DENSITY OUTSIDE REGION OF INTEREST IN MG/CC.
 XLAMDA-WAVELENGTH OF MONOCHROMATIC, COHERENT LIGHT SOURCE IN


```

MICRONS. AND XLAMDA ON THIRD DATA CARD IN (2F10.5) FORMAT
RHOINF AND XLAAMD ON THIRD DATA CARD IN (2F10.5) FORMAT
MODE=1 REFRACTIVE INDEX SUPPLIED THROUGH SUBROUTINE
      AND RECOMPUTED THE PROGRAM GENERATES FRINGE DATA
      AND RECOMPUTES THE REFRACTIVE INDEX FROM
      THE GENERATED FRINGE DATA.
MODE=2 BY INPUT DATA. REFRACTIVE INDEX SUPPLIED AT GRID PCINTS
      BY INPUT DATA. PROGRAM PROCEEDS AS IN MODE 1
MODE=3 FRINGE DATA SUPPLIED, PROGRAM GENERATES
      DENSITY FIELD.
MODE=4 SAME AS MODE=3 EXCEPT FRINGE DATA IS RECOM-
      PUTED AS PER MODE=2.
NP NUMBER OF EQUALLY SPACED
NT NUMBER OF VIEWS SUPPLIED
KSYM SYMMETRY OF FIELD 0-4 AXIS OF SYMMETRY
      4 -98 DATA REPEATS EVERY KSYM
      DEGREES. FIELD
      99 AXIS SYMMETRIC FIELD
RMAX RADIUS OF CIRCULAR REGION IN CENTIMETERS
FILTER=(0.-1.) DETERMINES SPAN OVER WHICH AVERAGING OCCURS
THE ABOVE INFORMATION ON THE FOURTH DATA CARD(4I10,2F10.5).
X(I) VECTOR OF GRID POINTS ALONG THETA = 0 DEGREES
      X(1)=-RMAX X(NP)=+RMAX
Y(J) VECTOR OF GRID POINTS ALONG THETA=90 DEGREES
      Y(1)=-RMAX Y(NP)=+RMAX
A(I,J) DENSITY OR REFRACTIVE INDEX AT THE POINT X(I),Y(J).
RB(1) VECTOR OF POINTS ON THE HCLOGRAPHIC PLATE RB(1)=-2 RMAX
RB(2 NP)=2 RMAX. GRID SPACING OF RAYS. DR=2*RMAX/(NP-1)
DR SPACING OF VIEWING ANGLES IN DEGREES
TH(K) VECTOR OF FRINGE SHIFT INFORMATION AT THE POINT(RB(I),TH(K)).
B(I,K) IS COPIED INTO BB(I,K). THE VALUE OF THE INSIDE
INTEGRATION IS THEN STORED IN B(I,K).
DASYM(K) SYMMETRY OF DATA(B(I,K). 0 NC SYMMETRY
      1 DATA SYMMETRIC ABOUT RB=0.
IF DASYM = 1.0 ONLY (NP+1)/2 DATA POINTS SHOULD BE FURNISHED.
BD(L) IS A WORK VECTOR USED BY THE PROGRAM.
FOR MODE=1 OR MODE=2 THE FIFTH DATA CARD IS THE VECTOR
TH(K) IN (8F10.5) FORMAT
FOR MODE 2 OPERATION THE REFRACTIVE INDEX FOLLOWS IN 8F10.5
FORMAT.
FOR MODE=3 AND MODE=4 OPERATION, THE FIFTH DATA CARD IS
TH(1) AND DASYM(1) IN (2F10.5) FORMAT. THIS IS FOLLOWED
BY THE FRINGE INFORMATION FOR THAT VIEW (B(I,1) ETC UNTIL
ALL VIEWS AND FRINGE SHIFT HAS BEEN SUPPLIED
IF AXIS OF SYMMETRY EXISTS, THETA=0. MUST CORRESPOND TO ONE OF
THE AXIS OF SYMMETRY.

```



```

READ(5,100) MODE,NP,NT,KSYM,RMAX,FILTER
WRITE(6,106)
WRITE(6,109) NMAP
WRITE(6,112) (ITT(I),I=1,12)
WRITE(6,108) RHOINF,XLAM
FNP=FLOAT(NP)
DR=2.*RMAX/(FNP-1)
WRITE(6,101)
WRITE(6,102) MODE,NP,NT,KSYM,RMAX,DR,FILTER
N=(NP+1)/2
NPL=(NP-1)/2
NPP=2*NPL-1
MAX=NP+NPL
RM2=RMAX**2
NP5=3*NPL-2
FNP5=FLOAT(NP5)
NPM1=NPL-1
FT2=FILTER*FILTER

*****ZERO MATRICES AND SET GRID *****

DO 2 I=1,NP
DO 1 J=1,NP
1 A(I,J)=0.0
2 B(I,K)=0.0
X(I)=-RMAX
Y(I)=X(I)
DO 3 I=2,NP
X(I)=X(I-1)+DR
3 Y(I)=X(I)

*****
GO TO (4,4,29,29),MODE

*****READ VIEWING ANGLES AND SET SIN AND COSINE FOR MODE=1,2*****

4 READ(5,103) (TH(K),K=1,NT)
DC 5 K=1,NT
THETA=TH(K)/57.296
CC(K)=COS(THETA)
5 SS(K)=SIN(THETA)

*****
IF(MODE.EQ.1) GO TO 7

*****READ REFRACTIVE INDEX FOR MODE=2 OPERATION*****

```



```

DO 6 I=1,NP
6 READ(5,103)(A(I,J),J=1,NP)
*****
GO TO 9
7 IF(KSYM.EQ.99) GO TO 13
*****SET REFRACTIVE INDEX AND WRITE SAME FOR MODE ONE OPERATION*****
DO 8 I=1,NP
DO 8 J=1,NP
XI=X(I)
YJ=Y(J)
CALL INPUT(XI,YJ,VAL)
8 A(I,J)=VAL
S WRITE(6,113)
K=1
K21=21
11 WRITE(6,106) (X(I),I=K,K21)
WRITE(6,110)
DO 12 I=1,NP
NN=NP-I+1
12 WRITE(6,111) Y(NN),(A(J,NN),J=K,K21)
IF(K21.EQ.NP) GO TO 150
K=K21+1
K21=K21+21
IF(K21.GT.NP) K21=NP
GO TO 11
150 A(1,1)=-1.0
A(1,2)=1.0
CALL CTRMAP(A,NMAP,NP,NP)
WRITE(6,112)(ITT(I),I=1,12)
CALL CONTUR(A,NP,NP,101,CL,NL,ITT,IW,IH,LTG)
GO TO 15
*****
*****SET REFRACTIVE INDEX FOR AXISYMETRIC CASE*****
13 DO 14 I=1,NP
14 CALL INPUT(X(I),0,A(I,N))
*****
15 IF(MODE.EQ.2) GO TO 19

```



```

*****INTEGRATE FOR FINGE SHIFT FOR MODE ONE CASE*****
DO 18 K=1,NT
R=-RMAX
B(1,K)=0.0
B(NP,K)=0.0
DO 18 I=2,NPM1
R=R+DR
PI=SQRT(RM2-R**2)
DP=2.*PI/FNP5
P=-PI
DO 16 J=1,NP5
YJ=R*CC(K)+P*SS(K)
XI=-R*SS(K)+P*CC(K)
CALL INPUT(XI,YJ,VAL)
P=P+DP
16 BD(J)=VAL
SUM=0.
NPP2=NPM1-2
DO 17 J=1,NPP2,2
*****INTEGRATION USES SIMPSON'S RULE *****
17 SUM=SUM+BD(J)+4.*BD(J+1)+BD(J+2)
18 B(I,K)=SUM*DP/3.
GO TO 34
*****INTEGRATE FOR FINGE SHIFT FOR MODE TWO CASE*****
15 K=0
20 K=K+1
IF(K.GT.NT) GO TO 33
IF(TH(K).EQ.0.) GO TO 23
IF(TH(K).EQ.90.) GO TO 26
R=-RMAX
B(1,K)=0.0
B(NP,K)=0.0
DO 22 L=2,NPM1
SUM=0.
R=R+DR
PI=SQRT(RM2-R**2)
DP=2.*PI/FNP5
P=-PI
DO 21 LL=1,NP5
XN=-R*SS(K)+P*CC(K)
YN=R*CC(K)+P*SS(K)
LINEAR INTERPOLATE FOR VALUE OF REFRACTIVE INDEX*****

```



```

I=(XN+RMAX+DR)/DR
J=(YN+RMAX+DR)/DR
XD=(XN-X(I))/DR
YD=(YN-Y(J))/DR
VAL=A(I,J)+XD*(A(I+1,J)-A(I,J))
VAL=VAL+YD*(A(I,J+1)-A(I,J+1))-VAL)
**
SUM=SUM+VAL*DP

```

```

21 P=P+DP
22 B(L,K)=SUM
   GO TO 20
23 DO 25 J=1,NP
   B(J,K)=0.0
   DO 24 I=2,NP
24 B(J,K)=B(J,K)+ (A(I-1,J)+A(I,J))
25 B(J,K)=DR*B(J,K)/2.
   GO TO 20
26 DO 28 I=1,NP
   L=NP+1-I
   B(L,K)=0.0
   DO 27 J=2,NP
27 B(L,K)=B(L,K)+A(I,J-1)+A(I,J)
28 B(L,K)=DR*B(L,K)/2.
   GO TO 20

```

***** READ DATA FOR MODE THREE OR FOUR OPERATION *****

```

29 DO 32 I=1,NT
   READ(5,103) TH(I), DASYM(I)
   IF(DASYM(I).EQ.1.) GO TO 30
   READ(5,103) (B(J,I),J=1,NP)
   GO TO 32
30 READ AND COPY SYMETRIC DATA
   READ(5,103) (B(J,I),J=1,N)
   L=N+1
   DO 31 J=L,NP
   K=NP-J+1
31 B(J,I)=B(K,I)
**
32 CONTINUE

```

```

33 IF(MODE.EQ.5) GO TO 63

```


*****SET RADIUS VECTOR AND EXTEND FRINGE INFORMATION TO TWICE RMAX*****

```

34 RB(1)=-2.*RMAX
DO 35 I=2,NPP
35 RB(I)=RB(I-1)+DR
DO 38 I=1,NT
Q1=B(1,I)
Q2=(B(2,I))-B(1,I))/DR
CALL COEF(Q1,Q2,-RMAX,E,G,C)
DO 36 J=1,NPL
36 BB(J,I)=F1(E,G,C,RB(J))
DO 37 K=1,NP
37 BB(K+NPL,I)=B(K,I)
Q1=B(NP,I)
Q2=(B(NP,I))-B(NP-1,I))/DR
CALL COEF(Q1,Q2,RMAX,E,G,C)
L=NP+NPL
DO 38 K=L,NPP
38 BB(K,I)=F1(E,G,C,RB(K))

```

*****CALCULATE VALUE OF INSIDE INTEGRAL *****

```

DO 43 I=1,NT
DC 43 J=1,NP
M=NPL+J
BD(1)=0.
DO 39 K=1,MAX
MKP=M+K
MKM=M-K
IF(MKP.GT.NPP) MKP=NPP
IF(MKM.LT.1) MKM=1
K1=K**2
39 BC(K+1)=(BB(MKP,I)+BB(MKM,I)-2.*BB(M,I))/(FLOAT(K1)*DR)
VAL=0.
K1=1
40 K2=K1+6
IF(K2.GT.MAX) GO TO 41
COTES SIXTH ORDER QUADATURE FORMULA *****
VAL=VAL+C1*(BD(K1)+BD(K2))+C2*(BC(K1+1)+BD(K2-1))+C3*(BD(K1+2)+BD(
1K2-2))+C4*BD(K1+3)
K1=K2
GC TO 40
41 SUM=0.
CCNTTRIBUTION OF LAST TERMS
DO 42 K=K1,MAX

```



```

42 SUM=SUM+BD(K)+BD(K+1)
SUM COTES PLUS LAST TERMS PLUS INTEGRATION FROM 2 RMAX TO INFINITY
43 B(J,I)= VAL+SUM/2.-.666667*BB(M,I)/RMAX
IF(KSYM.LT.99) GO TO 48

```

```

*****

```

```

***** INTEGRATE OVER THETA FOR AXISYMETRIC CASE *****

```

```

DEL=-.004421
M=1
TH(1)=0.0
SS(1)=0.0
DO 44 I=2,19
TH(I)=TH(I-1)+5.
44 SS(I)=SIN(TH(I))/59.296)
WRITE(6,107)
DO 47 I=1,NP
DO 45 K=1,19
DR=-X(I)*SS(K)
L=(R+RMAX+DR)/DR
IF(L.GE.NP) GO TO 460
IF(L.LT.1) GO TO 460
LP2=L+2
LP1=L+1
LM1=L-1
IF(LP2.GT.NP) LP2=NP
IF(LM1.LT.1) LM1=1
P=(R-X(L))/DR
COF3=.1666666*(B(LP2,K)-B(LM1,K))-.5*(B(LP1,K)-B(L,K))
COF2=.5*(B(LP1,K)+B(LM1,K))-B(L,K)
CCF1=-.1666666*B(LP2,K)+B(LP1,K)-.3333333*B(LM1,K)-.5*B(L,K)
P2=P*P
***** AMOUNT OF FILTERING DEPENDS ON FT2=FILTER*FILTER*****
45 BD(K)=P*(P2+FT2)*COF3+(P2+.666666*FT2)*COF2+P*COF1+B(L,K)
TRAPEZOIDAL INTEGRATION ON THETA *****
SUM=0.0
DO 46 K=2,19
SUM=SUM+BD(K)+BD(K-1)
46 CONTINUE
A(I,1)=SUM*DEL
460 CONTINUE
OUTPUT IS DENSITY FIELD IF MODE=3*****
IF(MODE.LT.3) GO TO 47
A(I,2)=RHOINF+.4443*XLAMD*A(I,1)
47 WRITE(6,105) X(I),A(I,N),A(I,1),A(I,2),BB(NPL+I,1),B(I,1)

```


[illegible]

```

48 IF (MODE.LT.3) GO TO 75
   GO TO 75
   M=NT+1
   IF (KSYM.EQ.0) GO TO 51
   IF (KSYM.GT.4) GO TO 53

```

***GENERATE ADDITIONAL DATA DEPENDING ON SYMETRY OF FIELD**

```

DT=TH(2)-TH(1)
NTP=NT
DC 50 J=1,KSYM
K=J*NT
DO 49 I=1,NTP
KK=K+I
TH(KK)=TH(KK-1)+DT
KM=K-I+1
DC 49 L=1,NP
B(L,KK)=B(L,KM)
NTP=2*NTP
M=KK+1

```

[illegible]

51 $TH(M) = TH(I) + 180$.
 DO 52 I = 1, NP
 K = (NP - I + 1)
 52 $B(K, M) = B(I, 1)$


```

*****INTEGRATE ON THETA FOR ASYMETRIC FIELD*****
MD=M-1
DEL=-1./(2.*3.1416*FLOAT(MD))
DO 56 I=1,M
  CC(I)=COS(TH(I)/59.296)
  SS(I)=SIN(TH(I)/59.296)
56 DO 61 LL=1,NP
  J=NP+1-LL
  DC 60 I=1,NP
  A(I,J)=0.
  DC 58 K=1,M
  R=Y(J)*CC(K)-X(I)*SS(K)
  NN=(R+R*MAX(DR))/DR
  IF(NN*GE.NP) GO TO 60
  IF(NN.LT.1) GO TO 60
  LP2=NN+2
  LP1=NN+1
  LM1=NN-1
  IF(LP2.GT.NP) LP2=NP
  IF(LM1.LT.1) LM1=1
  P=(R-X(NN))/DR
  COF3=.1666666*(B(LP2,K)-B(LM1,K))-.5*(B(LP1,K)-B(NN,K))
  COF2=.5*(B(LP1,K)+B(LM1,K))-B(NN,K)
  COF1=-.1666666*B(LP2,K)+B(LP1,K)-.333333*B(LM1,K)-.5*B(NN,K)
  P2=P*P
  *****AMOUNT OF FILTERING DEPENDS ON FT2=FILTER*****
  58 BD(K)=P*(P2+FT2)*COF3+(P2+.666666*FT2)*COF2+P*COF1+B(NN,K)
  *****INTEGRATE OVER THETA USING TRAPEZOIDAL INTEGRATION*****
  VAL=0.0
  DO 59 L=2,M
  59 VAL=VAL+BD(L)+BD(L-1)
  A(I,J)=VAL*DEL/2.
  *****
  60 CONTINUE
  61 CONTINUE
  *****
  NFN=NP+NPL
  IF(MODE.LT.4) GO TO 63
  IF(MODE.EQ.4) MODE=5
  GO TO 19
  63 IF(MODE.LT.3) GO TO 65
  *****CHANGE REFRACTIVE INDEX FIELD TO DENSITY FIELD*****

```



```

65 WRITE(6,115)
66 WRITE(6,113)
*****WRITE REFRACTIVE INDEX OR DENSITY FIELD*****
K=1
K21=21
67 WRITE(6,106)
WRITE(6,110) (X(I), I=K, K21)
DO 68 I=1, NP
NN=NP-I+1
68 WRITE(6,111) Y(NN), (A(J, NN), J=K, K21)
IF(K21.EQ.NP) GO TO 690
K=K21+1
K21=K21+21
IF(K21.GT.NP) K21=NP
GO TO 67
*****
69C A(1,1)=-1.0
A(1,2)=1.0
CALL CTRMAP(A, NMAP, NP, NP)
WRITE(6,112) (ITT(I), I=1, 12)
CALL CONTUR(A, NP, NP, 101, CL, NL, ITT, IW, IH, LTG)
69 WRITE(6,116)
*****WRITE FRINGE SHIFT INFORMATION*****
WRITE(6,104) (TH(K), K=1, NT)
DC 70 I=N, NPN
70 WRITE(6,105) RB(I), (BB(I, J), J=1, NT)
WRITE(6,112) (ITT(I), I=1, 12)
WRITE(6,116)
WRITE(6,104) (TH(K), K=1, NT)
DO 700 J=1, NT
WRITE(6,103) TH(J)
WRITE(6,103) (BB(I, J), I=N, NPN)
700 CONTINUE

```



```

WRITE(7,112) (IT(I), I=1,12)
WRITE(7,103) RHOINF,XLAM
WRITE(7,100) MODE, NP, NT, KSYM, RMAX, FILTER
DO 710 J=1, NT
  WRITE(7,103) TH(J)
  WRITE(7,103) (BB(I, J), I=N, NPN)
710 CONTINUE

  WRITE(6,117)
  WRITE(6,104) (TH(K), K=1,M)
  DO 71 I=1, NP
    WRITE(6,105) X(I), (B(I, J), J=1, M)
    WRITE(6,112) (ITT(I), I=1,12)
71 CONTINUE
  STOP
  END

SUBROUTINE COEF(VAL, SLOPE, U, CU2, CU, CONST)
**
**
** SUBROUTINE COEF CALCULATES THE COEFFICIENTS USED BY THE
** FUNCTION (F1) TO EXPAND THE FRINGE INFORMATION TO 2 RMAX
**
**
**
U2=U**U
CU2=-SLOPE/U-VAL/U2
CU=-VAL/U-3.**U*CU2
CONST=VAL-CU**U-CU2*U2
RETURN
END

SUBROUTINE INPUT(XI, YJ, VAL)
**
**
** SUBROUTINE INPUT IS SUPPLIED BY THE USER FOR MODE 1
** OPERATION. THE MAIN PROGRAM PASSES THE POINT (XI, YJ) AND
** INPUT, SUPPLIES THE VALUE OF THE REFRACTIVE INDEX AT THAT
** POINT USING ANY ARITHMETIC OR LOGIC STATEMENT NECESSARY.
**
**
** VAL=0.
** VAL=F(XI, YJ)
** RETURN
** END

```


0.0243	0.0194	0.04333	0.0664	0.03333	0.05434	0.07108	0.08521
0.38086	0.43898	0.50877	0.57224	0.62221	0.72459	0.78335	0.87233
0.91073	0.96214	0.00821	0.04789	0.08431	0.1432	0.1956	0.25399
1.17208	1.18054	1.18359	1.18122	1.17341	1.16017	1.14147	1.11732
1.06501	1.05260	1.01201	0.94125	0.83110	0.68572	0.5458	0.4220
0.65018	0.57933	0.50655	0.44126	0.38311	0.32944	0.28047	0.23634
0.19967	0.16483	0.14179	0.12068	0.10140	0.08595	0.07059	0.05459
0.03325	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
67.50000							
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.13010	0.15680	0.18588	0.21685	0.25177	0.28717	0.32823	0.37235
0.1948	0.49414	0.52874	0.58699	0.65220	0.71481	0.77276	0.82613
0.87493	0.91914	0.95877	0.99379	1.02479	1.05000	1.07118	1.08772
1.09964	1.06911	1.09553	1.0749	1.00835	0.89411	0.73559	0.52619
1.02718	0.99704	0.96220	0.92264	0.87835	0.82934	0.77551	0.71709
1.04589	0.58918	0.52663	0.47135	0.42120	0.37384	0.32951	0.28571
0.25089	0.21614	0.18539	0.15649	0.12992	0.10528	0.08101	0.05712
0.03186	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
82.50000							
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.12894	0.15940	0.19399	0.23477	0.27524	0.31651	0.36336	0.4129
0.46575	0.52001	0.57776	0.63551	0.69598	0.75454	0.80925	0.85971
0.90592	0.94785	0.98548	1.01881	1.04781	1.07247	1.09638	1.10870
1.12024	1.12737	1.13008	1.12835	1.12172	1.11152	1.09638	1.07674
1.05258	1.02388	0.99063	0.95282	0.91042	0.86342	0.81181	0.75556
0.69500	0.63643	0.57700	0.52067	0.46628	0.41372	0.36369	0.31676
0.27207	0.23237	0.19395	0.15939	0.12895	0.10126	0.07521	0.05114
0.002755	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

THE ASYMMETRIC CASE TEST CASE OF FIGURE 8

RUN UNDER MODE 3

NECESSARY DATA CARDS

VERETT ASYMMETRIC TEST GAUSSIAN ON (X)

0.79447	0.79452	0.79454	0.79457	0.79459	0.79462	0.79464
0.72004	0.56784	0.49240	0.41969	0.34960	0.28295	0.22047
0.16559	0.07760	0.04782	0.02366	0.01076	0.00466	0.00604
0.00567	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
52.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.10243	0.14333	0.16664	0.33333	0.54334	0.7108	0.8521
0.38086	0.50877	0.57724	0.20163	0.23424	0.27833	0.32723
0.72480	0.72494	0.72501	0.65221	0.72459	0.72466	0.72473
0.72536	0.72543	0.72556	0.72508	0.72515	0.72522	0.72529
0.72591	0.72605	0.72612	0.72563	0.72570	0.72577	0.72584
0.65018	0.72605	0.44125	0.72619	0.72626	0.72633	0.72640
0.19967	0.14179	0.12068	0.38311	0.32944	0.28047	0.23634
0.03325	0.00000	0.00000	0.10140	0.08595	0.07059	0.05459
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
67.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.13010	0.18588	0.21689	0.31811	0.5717	0.8101	0.10520
0.1948	0.52874	0.58699	0.25177	0.28727	0.32823	0.37235
0.41948	0.71525	0.71534	0.65222	0.71481	0.71490	0.71499
0.71507	0.71595	0.71604	0.71542	0.71551	0.71560	0.71569
0.71577	0.71665	0.71674	0.71613	0.71621	0.71630	0.71639
0.71648	0.71665	0.47135	0.71683	0.71691	0.71700	0.71709
0.64989	0.52663	0.47135	0.42120	0.37384	0.32951	0.28838
0.25089	0.18539	0.15649	0.12992	0.10528	0.08101	0.05712
0.03186	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
82.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.12894	0.19399	0.2477	0.27524	0.5118	0.7517	0.10129
0.46575	0.57776	0.63557	0.27224	0.31651	0.36333	0.41329
0.75466	0.75474	0.75509	0.69598	0.75454	0.75458	0.75462
0.75497	0.75505	0.75540	0.75481	0.75485	0.75489	0.75493
0.75529	0.75536	0.75540	0.75513	0.75517	0.75521	0.75525
0.69500	0.57700	0.52067	0.46624	0.41372	0.36369	0.31676
0.27207	0.19395	0.15939	0.12899	0.10126	0.07521	0.05114
0.02755	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

CASE #5
 THE ASYMMETRIC TEST CASE OF FIGURE 8, DISPLACED FROM THE
 CENTER BY 0.25 IN THE X AND Y DIRECTIONS
 RUN UNDER MODE 1

YJ=YJ-0.25
 Y2=YJ*YJ
 XI=XI-0.25
 X2=XI*XI
 VAL=(1.-Y2)*EXP(-2.*X2)
 R2=Y2+X2
 IF(R2.GT.1.5) VAL = 0.
 RETURN
 END

NECESSARY DATA CARDS

VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
 QUARE ON (Y)

CASE #5
 MODE 1 (DISPLACED) STANDARD CASE

1	.6941	101	12	37.5	52.5	0	2.0	67.5	82.5	97.5	112.5
07.5	22.5	157.5	172.5								
127.5	142.5										

CASE #7
 THE ASYMMETRIC TEST CASE OF FIGURE 8, DISPLACED FROM THE
 CENTER BY 0.25 IN THE X AND Y DIRECTIONS
 RUN UNDER MODE 3

NECESSARY DATA CARDS
 VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
 QUARE CN (Y)
 EVERETT INTRPL OF FIGURE 8 (DISPLACED)
 CASE #7

1	.6941	101	12	37.5	52.5	0	2.0	67.5	82.5	97.5	112.5
07.5	22.5	157.5	172.5								
127.5	142.5										

CONTINUE ENTERING FRINGE SHIFT INFORMATION
 OBTAINED FROM CASE #5
 THE MODIFIED OUTPUT FRINGE SHIFT INFORMATION

[illegible]

[illegible]

0.73738	0.72419	0.71760	0.71100	0.70441	0.69782	0.69122
0.68463	0.67145	0.66485	0.65826	0.65167	0.64507	0.63848
0.56495	0.43683	0.37237	0.32079	0.26958	0.23162	0.19364
0.16064	0.11777	0.09926	0.08287	0.06915	0.05184	0.02845
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
67.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.0196	0.0692	0.0968	0.1442	0.13980	0.16770	0.19773
0.22941	0.30178	0.34431	0.39062	0.43389	0.49051	0.55138
0.61209	0.73846	0.80225	0.87492	0.94171	0.99500	0.90830
0.89159	0.85818	0.84147	0.82476	0.80806	0.79135	0.77464
0.75794	0.72453	0.70782	0.69111	0.67441	0.65770	0.64099
0.62429	0.59087	0.57417	0.55746	0.54075	0.52405	0.50734
0.44903	0.35524	0.31279	0.27999	0.23597	0.20452	0.17372
0.14630	0.09564	0.07210	0.04863	0.01902	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
82.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.06042	0.1167	0.13996	0.17295	0.19942	0.22545	0.23668
0.33364	0.43338	0.48725	0.55990	0.64716	0.74033	0.83939
0.77761	0.89152	0.93510	0.99097	1.04714	1.08350	1.00589
0.97778	0.93152	0.90848	0.88527	0.86212	0.83901	0.81587
0.92776	0.74651	0.72336	0.70025	0.67710	0.65400	0.63085
0.60774	0.56149	0.53839	0.51523	0.49210	0.46898	0.44585
0.39427	0.29899	0.25639	0.21654	0.18042	0.14745	0.11807
0.09035	0.04324	0.01628	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
97.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.10064	0.16003	0.19471	0.22338	0.23233	0.25137	0.27587
0.41434	0.52151	0.57735	0.63533	0.69607	0.75289	0.81303
0.86363	0.97534	1.04619	1.09170	1.12190	1.15226	1.02978
0.80046	0.74217	0.71302	0.68388	0.65473	0.62559	0.59661
0.56729	0.50900	0.47986	0.45071	0.42156	0.39242	0.36327
0.31639	0.23113	0.19408	0.15964	0.12821	0.10094	0.07486
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

1.03398	1.08017	1.12132	1.15834	1.19002	1.21685	1.18000	1.4316
1.10631	1.06947	1.03262	1.09578	1.05893	1.02273	1.8524	1.84839
1.01155	1.07747	1.03786	0.70101	0.66416	0.62732	0.59047	0.55363
0.51678	0.47993	0.44309	0.40624	0.36940	0.33255	0.29571	0.25886
0.18562	0.11218	0.04893	0.01192	0.06005	0.09448	0.11646	0.11135
-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
172.50000							
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.14890	0.07939	0.00995	0.08203	0.16579	0.19214	0.22718	0.20347
-0.14931	-0.56750	-0.63965	0.70689	0.77145	0.83088	0.88747	-0.41442
0.98826	1.03143	1.07111	1.10619	1.13823	1.16517	1.13620	0.93913
1.07827	1.04930	1.02034	0.99137	0.96241	0.93344	0.90475	1.10724
0.84654	0.81758	0.78861	0.75564	0.73068	0.70171	0.67275	0.87551
0.61481	0.58585	0.55688	0.52791	0.49895	0.46998	0.44102	0.64378
-0.33161	-0.24794	-0.16397	0.07949	-0.00292	-0.08149	-0.15018	-0.41205
0.22861	0.18649	0.16397	0.07949	0.00000	0.00000	0.00000	0.20405
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ADDITIONAL SUBROUTINES

ADDITIONAL SUBROUTINES

SLBROUTINE CTRMAP(A,NMAP,N,M)

THIS SUBROUTINE WILL GIVE A MAP OF THE NUMBERS CONTAINED ARRAY A
FOUR PARAMETERS MUST BE FURNISHED TO THE SUBROUTINE

```

A IS THE NAME OF THE ARRAY TO BE MAPPED
N IS THE NUMBER OF LINES IN THE MAP
M IS THE WIDTH OF THE LINE, MAXIMUM IS 115
MAP IS A FIXED POINT IDENTIFICATION NUMBER FOR THE MAP

```

TWENTY SYMBOLS ARE USED IN THE PRODUCTION OF THE MAP
THEY ARE: A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z.

AT THE TOP OF THE MAP THE VALUES OF THE SYMBOLS ARE LISTED
THE USER SHOULD REALIZE THAT THIS IS AN OUTPUT SUBROUTINE
THAT WILL PRODUCE A DIGITAL PLOT EVERY TIME IT IS CALLED

THE USER IS ALSO WARNED THAT THIS SUBROUTINE IS NOT GOING TO INTERPOLATE FOR SUPPLEMENTARY POINTS, THE MAP IS PRODUCED WITH THE ARRAY A EXCLUSIVELY

CODED BY: PROFESSOR GILLES CANTIN, (59CI) IN 1964 FOR THE CDC/1604
AND ADAPTED FOR THE IBM/67 SEVERAL TIMES, BY THE AUTHOR
THIS VERSION IS DATED OCTOBER 1, 1969.

```

DIMENSION LINE(115), ISYMB(42), BV(21), A(N,M)
DATA ISYMB/1H,1HO,1H,1HA,1H,1HB,1H,1HC,1H,1HD,1H,1HE,
1,1HF,1H,1HG,1H,1HH,1H,1HI,1H,1HJ,1H,1HQ,1H,1HR,1H,1HS,
2,1H,1HT,1H,1HU,1H,1HV,1H,1HW,1H,1HX,1H,1HY,1H,1HZ/
DATA IBLK/1H /
AMIN=1.E+70
DO 6 I=1,N
DO 5 J=1,M
5 AMIN=AMIN1 (AMIN, A(I,J)) .
5 CCNTINUE

```



```

DO 8 I=1,N
DO 7 J=1,M
7 A(I,J)=A(I,J)-AMIN
8 CONTINUE
AMAX=-1.E+70
DO 11 I=1,N
DO 10 J=1,M
10 AMAX=AMAXI(AMAX,A(I,J))
11 CONTINUE
RCE=AMAX
IF(ABS(RGE)-1.0E-10) 12,12,13
12 WRITE(6,1400) RGE,AMAX,AMIN
1400 FORMAT(/,5X,13H THE RANGE IS,E15.6,/,5X,13H
15X,13H MINIMUM IS,E15.6)
RETURN
13 CONTINUE
SCF=40./AMAX
DO 21 I=1,N
DO 20 J=1,M
20 A(I,J)=SCF*A(I,J)
21 CONTINUE
DC 30 I=1,21
AI=FLOAT(I-1)
BV(I)=(2.*AI/SCF)+AMIN
WRITE(6,1050)
WRITE(6,1050) BV(1),BV(1),BV(21)
WRITE(6,1300) BV(2),BV(3),BV(4),BV(5),BV(6)
WRITE(6,1100) BV(7),BV(8),BV(9),BV(10),BV(11)
WRITE(6,1200) BV(12),BV(13),BV(14),BV(15),BV(16)
WRITE(6,1210) BV(17),BV(18),BV(19),BV(20),BV(21)
WRITE(6,1220) BV(17),BV(18),BV(19),BV(20),BV(21)
M1=M+1
DO 50 K=1,N
DO 40 J=1,M
AJ=A(K,J)+2.50001
JJ=INT(AJ)
40 LINE(J)=ISYMB(JJ)
41 IF(M1-115) 41,41,46
41 CONTINUE
DC 45 I=M1,115
45 LINE(I)=IBLK
46 CONTINUE
50 WRITE(6,2000) LINE
DO 61 I=1,N
DC 60 J=1,M

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CTR00360
CTR00370
CTR00380
CTR00390
CTR00400
CTR00410
CTR00420
CTR00430
CTR00440
CTR00450
CTR00460
CTR00470
CTR00480
CTR00490
CTR00500
CTR00510
CTR00520
CTR00530
CTR00540
CTR00550
CTR00560
CTR00570
CTR00580
CTR00590
CTR00600
CTR00610
CTR00620
CTR00630
CTR00640
CTR00650
CTR00660
CTR00670
CTR00680
CTR00690
CTR00700
CTR00710
CTR00720
CTR00730
CTR00740
CTR00750
CTR00760
CTR00770
CTR00780
CTR00790
CTR00800
CTR00810
CTR00820
CTR00830

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CTR000840
CTR000850
CTR000860
CTR000870
CTR000880
CTR000890
CTR000900
CTR000910
CTR000920
CTR000930
CTR000940
CTR000950
CTR000960
CTR000970
CTR000980
CTR000990
CTR01000

```

60 A(I,J)=A(I,J)/SCF +AMIN
61 CONTINUE
  WRITE(6,2500) NMAP
2500 FORMAT(//,5X,4H MAP,I3)
1000 FORMAT(1H1)
1050 FORMAT(//)
1100 FORMAT(5X,3H A=,F8.3,3X,3H B=,F8.3,3X,3H C=,F8.3,3X,3H D=,F8.3,
      13X,3H E=,F8.3)
1200 FORMAT(5X,3H F=,F8.3,3X,3H G=,F8.3,3X,3H H=,F8.3,3X,3H I=,F8.3,
      13X,3H J=,F8.3)
1210 FORMAT(5X,3H Q=,F8.3,3X,3H R=,F8.3,3X,3H S=,F8.3,3X,3H T=,F8.3,
      13X,3H U=,F8.3)
1220 FORMAT(5X,3H V=,F8.3,3X,3H W=,F8.3,3X,3H X=,F8.3,3X,3H Y=,F8.3,
      13X,3H Z=,F8.3)
1300 FORMAT(5X,3H O=,F10.6,5X,7H RANGE(,E15.6,5X,E15.6,2H ))
2000 FORMAT(2X,115A1)
      END

```

CNTR00010
CNTR00020

.....

SUBROUTINE CNTR

1. IDENTIFICATION

- A. NAME: GENERATE CCNTOUR GRAPH (CNTR) - J5
- B. PROGRAMMER: BERNADETTE R.PEAVEY, 7 JULY 1969

2. PURPOSE

CNTR GENERATES A CONTOUR GRAPH ON WHICH ONE OR MORE
(USUALLY MORE) CONTOUR LEVELS ARE DRAWN; THAT IS, GIVEN A MATRIX
OF NUMERICAL VALUES OF $Z=F(X,Y)$, CCNTR FINDS THE LCCI OF
SPECIFIED DISCRETE VALUES OF Z AND PLOTS THESE LOCI (CONTOUR
LINES) USING THE OFFLINE PLOTTER.

3. USAGE

A. DEFINITIONS

IN WHAT FOLLOWS THE WORD GRAPH OR CONTOUR GRAPH WILL BE

CNTR00030
CNTR00040
CNTR00050
CNTR00060
CNTR00070
CNTR00080
CNTR00090
CNTR0100
CNTR0110
CNTR0120
CNTR0130
CNTR0140
CNTR0150
CNTR0160
CNTR0170
CNTR0180
CNTR0190
CNTR0200
CNTR0210
CNTR0220
CNTR0230

TAKEN TO MEAN A COMPLETE CONTOUR PICTURE; THAT IS, ONE PIECE
OR FRAME OF GRAPH PAPER ON WHICH ONE OR MORE (USUALLY MORE)
CONTOUR LEVELS ARE DRAWN.

A CONTOUR OR CONTOUR LEVEL WILL MEAN THE PLCT OF THE LOCUS
ON THE XY PLANE OF ALL Z EQUAL TO A CONSTANT VALUE. NORMALLY,
SUCH A CONTOUR WILL CONTAIN MORE THAN ONE CONTOUR SEGMENT.

A CONTOUR SEGMENT IS EITHER A CLOSED FIGURE (INTERIOR
CONTOUR SEGMENT) OR A CURVE, EACH END OF WHICH TERMINATES AT
A MARGIN OF THE CONTOUR GRAPH (EXTERIOR CONTOUR SEGMENT). IT
REPRESENTS, IN GENERAL, ONLY A PART OF THE LOCUS ON THE XY
PLANE OF ALL Z EQUAL TO SOME VALUE. FOR EXAMPLE, IF $Z = F(X, Y)$
REPRESENTS A RANGE OF THREE MCOUNTAINS OF EQUAL ALTITUDE, EACH
A CIRCULAR CONE, THEN EVERY CONTOUR SEGMENT WOULD APPEAR AS A
CIRCLE. THREE CIRCLES, ONE FOR EACH MCOUNTAIN, WOULD MAKE UP
ONE CONTOUR OR CONTOUR LEVEL. THE COMPLETE GRAPH WOULD APPEAR
AS THREE NESTS OF CONCENTRIC CIRCLES.

B. CALLING STATEMENT

CALL CONTUR(AM,M,N,MX,CL,NL,TITLE,IW,IH,LTG)

WHERE:

- 1) AM IS THE REAL*4 DATA MATRIX TO BE CCOUTURED AND PLOTTED.
IT IS A TWO-DIMENSIONAL ARRAY WHCSE ROW DIMENSION IS
PASSED TO CONTUR AS THE PARAMETER MX.
- 2) M IS AN INTEGER VARIABLE WHICH IS THE NUMBER OF ROWS IN THE
DATA MATRIX TO BE CONTOURED.
- 3) N IS AN INTEGER VARIABLE WHICH IS THE NUMBER OF COLUMNS IN
THE DATA MATRIX TO BE CONTOURED.
- 4) MX IS AN INTEGER WHICH SPECIFIES THE ROW DIMENSION OF AM.
THIS IS THE EXACT NUMBER APPEARING IN THE DIMENSION
STATEMENT DEFINING AM.
- 5) CL IS A REAL*4 ARRAY CONTAINING THE CONTOUR LEVELS TO BE
PLOTTED DIMENSIONED AT LEAST CL(INL).
- 6) NL IS AN INTEGER VARIABLE WHOSE ABSCLUTE VALUE IS THE
NUMBER OF CONTOUR LEVELS TO BE FCUND FOR THIS GRAPH. IF
NL IS NEGATIVE THEN CONTUR SCANS THE DATA MATRIX FOR THE
LOWEST AND HIGHEST LEVELS OF DETERMINE THE DELTA VALUE
FOR PRODUCING INL1 LEVELS OF CONTOURING. IF NL IS
POSITIVE, THEN CONTUR ASSUMES THE CL ARRAY CONTAINS

NL ENTRIES OF CONTOUR LEVELS TO BE PLOTTED.

- 7) TITLE IS A REAL*8 ARRAY DIMENSIONED TITLE(12). CONTOUR PICKS UP THE MAIN TITLE FROM TITLE(1)-TITLE(6). THE SUBTITLE IS PICKED UP FROM TITLE(7)-TITLE(12). IF THE USER WISHES HIS TITLES TO BE CENTERED THEN HE MUST STORE HIS CHARACTERS IN TITLE ACCORDINGLY.
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
- 8) IW IS AN INTEGER VARIABLE SPECIFYING THE WIDTH OF THE CONTOUR GRAPH IN INCHES (1 IW 9).
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
- 9) IH IS AN INTEGER VARIABLE SPECIFYING THE HEIGHT OF THE CONTOUR GRAPH IN INCHES (IH>0).
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
- 10) LTG IS A LOGICAL*1 ARRAY DIMENSIONED LTG(3) WHERE:
 - A) LTG(1)=.TRUE. REQUESTS LABELLING OF ALL EXTERIOR CONTOUR SEGMENTS AND THOSE INTERIOR CONTOUR SEGMENTS WHICH REPRESENT A LOCAL MAXIMUM.
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
 - LTG(1)=.FALSE. OMTS LABELLING OPTION.
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
 - B) LTG(2)=.TRUE. REQUESTS TIC MARKS AND CORRESPONDING SCALE VALUES ONE INCH APART ON THE EXTERIOR FRAME OF THE CONTOUR GRAPH.
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
 - LTG(2)=.FALSE. OMTS "TIC" OPTION.
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
 - C) LTG(3)=.TRUE. REQUESTS CONTOUR TO SUPERIMPOSE A ONE INCH BY ONE INCH STRAIGHT LINE GRID ON THE CONTOUR GRAPH.
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
 - LTG(3)=.FALSE. OMTS THE GRID OPTION.
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190

C. ERROR MESSAGES

- 1) "CONTOUR LINE AT LEVEL (E12.5) WAS TERMINATED AT X=(E12.5), Y=(E12.5) BECAUSE IT CONTAINED MORE THAN 1799 POINTS." (THE APPROPRIATE VALUES ARE PRINTED WHERE FORMATS ARE INDICATED)
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
- 2) "WIDTH OF CONTOUR GRAPH ILLEGAL." (IW.LE.0)
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
- 3) "HEIGHT OF CONTOUR GRAPH ILLEGAL." (IH.LE.0)
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190
- 4) "DATA MATRIX HAS ONLY ONE LEVEL." AFTER SCANNING THE DATA MATRIX FOR THE HIGHEST AND LOWEST LEVEL ENTRIES, CCNTUR FINDS THAT THE MATRIX TO BE CONTOURED CONTAINS THE SAME LEVEL VALUE IN ALL ENTRIES.
CNTR0720
CNTR0730
CNTR0740
CNTR0750
CNTR0760
CNTR0770
CNTR0780
CNTR0790
CNTR0800
CNTR0810
CNTR0820
CNTR0830
CNTR0840
CNTR0850
CNTR0860
CNTR0870
CNTR0880
CNTR0890
CNTR0900
CNTR0910
CNTR0920
CNTR0930
CNTR0940
CNTR0950
CNTR0960
CNTR0970
CNTR0980
CNTR0990
CNTR1000
CNTR1010
CNTR1020
CNTR1030
CNTR1040
CNTR1050
CNTR1060
CNTR1070
CNTR1080
CNTR1090
CNTR1100
CNTR1110
CNTR1120
CNTR1130
CNTR1140
CNTR1150
CNTR1160
CNTR1170
CNTR1180
CNTR1190

CNTR1200
CNTR1210
CNTR1220
CNTR1230
CNTR1240
CNTR1250
CNTR1260
CNTR1270
CNTR1280
CNTR1290
CNTR1300
CNTR1310
CNTR1320
CNTR1330
CNTR1340
CNTR1350
CNTR1360

- 5) "NUMBER OF LEVELS REQUESTED=0." (NL=0)
- 6) "NO GRAPH WILL BE PRODUCED." THIS MESSAGE FOLLOWS 2)-5) ABOVE.
- 7) "IW PARAMETER GREATER THAN 9. CONTUR WILL SET IW=9." PROCESSING CONTINUES WITH IW=9.

4. SUBROUTINES USED

THE SUBROUTINES DESCRIBED IN "THE PLCTTING PACKAGE FOR NPGS IBM 360/67" ARE USED TO DRAW THE CONTOUR GRAPH. SUBROUTINES WHICH FIND THE POINTS TO BE PLOTTED WERE PROVIDED BY DR. M.O. DAYHOFF OF THE NATIONAL BIOMEDICAL RESEARCH FOUNDATION, SILVER SPRING, MARYLAND.

SUBROUTINE PLOTT DRAWS THE INTERIOR AND EXTERIOR CONTOUR SEGMENTS AND LABELS (IF REQUESTED) THE EXTERIOR CONTOUR SEGMENTS. CONTUR DOES THE LABELLING OF INTERIOR SEGMENTS WHICH REPRESENT LOCAL MAXIMA.

5. RESTRICTIONS

A) INPUT

- 1) 1.LE.IW.LE.9
- 2) IH.GE.1
- 3) WHENEVER NL IS POSITIVE THE DATA MATRIX IS NOT SCANNED FOR THE MINIMUM AND MAXIMUM LEVELS; CONSEQUENTLY THE USER IS CAUTIONED AGAINST THE POSSIBILITY THAT NO GRAPH WILL BE PRODUCED IF
 - A) ALL ENTRIES IN THE DATA MATRIX ARE EQUAL
 - B) ENTRIES IN THE DATA MATRIX ARE ALL BELOW OR ALL ABOVE THE REQUESTED LEVELS.

B) OUTPUT

- 1) ACCURACY IS LIMITED BY THE LINEAR INTERPOLATION PROCESS USED IN FINDING THE VALUES OF THE PCINTS ALONG CONTOUR SEGMENTS. IT IS ALSO LIMITED BY THE RESOLUTION OF THE OFFLINE PLOTTER; I.E., .01 INCH IN BOTH THE X AND Y

CNTR1370
CNTR1380
CNTR1390
CNTR1400
CNTR1410
CNTR1420
CNTR1430
CNTR1440
CNTR1450
CNTR1460
CNTR1470
CNTR1480
CNTR1490
CNTR1500
CNTR1510
CNTR1520
CNTR1530
CNTR1540
CNTR1550
CNTR1560
CNTR1570
CNTR1580
CNTR1590
CNTR1600
CNTR1610
CNTR1620
CNTR1630
CNTR1640
CNTR1650

DIRECTIONS.

- 2) THE X-SCALE VALUES ALONG THE TIC MARKS ARE 1.0.LE.X.LE.N.
THE Y-SCALE VALUES ARE 1.0.LE.Y.LE.M.
- 3) ONLY UP TO 20 INTERIOR SEGMENTS WHICH REPRESENT
MAXIMA ARE LABELLED.

6. STORAGE REQUIREMENTS

CONTR AND ALL ITS SUBORDINATE SUBROUTINES REQUIRE 54,570
BYTES OF CORE.

7. HARDWARE CONFIGURATION

- A) IBM 360/67EQUIPMENT CONFIGURATION (INCLUDING SPOOLING DISKS,
ETC.) WITH APPROPRIATE SYSOUT AND SYSIN UNITS.

- B) CALCOMP MODEL 765 PLOTTER

8. REFERENCES

- A) DAYHOFF, M.O., "A CONTOUR-MAP PROGRAM FOR X-RAY CRYSTALLOGRAPHY"
COMMUNICATIONS OF ASSOCIATION FOR COMPUTING MACHINERY,
OCTOBER 1963
- B) JOHNSON, PATRICIA C., "PLOTTING PACKAGE FOR NPGS IBM 360/67",
TECHNICAL NOTE NO. 0211-03, FEBRUARY 1969
- C) HILLEARY, R.R., "J7-NPG-CONTCUR (F-60)", SEPTEMBER 1964.

9. MATHEMATICAL METHOD

THE ALGORITHM USED IN FINDING THE CONTOURS IS DEFINED IN
REFERENCE A).

SUBROUTINE CONTCUR(AM,M,N,MX,CL,AL,TITLE,IW,IH,LTG)

REAL*8 TITLE(1)

REAL*8 WIDTH/,WIDTH/,HEIGHT/,HEIGHT/,WHICH

DIMENSION AM(MX,1),CL(1)

DIMENSION REC(900), X(1800), Y(1800)

DIMENSION IPT(3,3),INX(8),INY(8)

DIMENSION /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,NQ,JT,

COMMON /PY,REC,CV, IPT,INX,INY,DL,RA,THE

1 COMMON /INTFAC/ X,Y

DIMENSION DITSX(5),DITSY(5)

CNTR1660
CNTR1670
CNTR1680
CNTR1690
CNTR1700
CNTR1710
CNTR1720
CNTR1730
CNTR1740
CNTR1750
CNTR1760
CNTR1770
CNTR1780
CNTR1790
CNTR1800
CNTR1810
CNTR1820
CNTR1830
CNTR1840
CNTR1850
CNTR1860
CNTR1870
CNTR1880
CNTR1890
CNTR1900
CNTR1910
CNTR1920
CNTR1930
CNTR1940
CNTR1950
CNTR1960
CNTR1970
CNTR1980
CNTR1990
CNTR2000
CNTR2010

CNTR2020
CNTR2030
CNTR2040
CNTR2050
CNTR2060
CNTR2070
CNTR2080
CNTR2090
CNTR2100
CNTR2110


```

LOGICAL*1 LTG(1), MINUS, LABL
CCOMMON/TABL/ TABC(20,6), JC
COMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITSOX,DITSXY, ICIR, LABL, MINUS
JC=0
LABL=LTG(1)
CHECK IW PARAMETER
WHICH=WIDTH
IF(IW) 1,1,2 WHICH
1  WRITE(6,60) WHICH
60  FCRMAT('0',T7,A8,'OF CONTOUR GRAPH ILLEGAL.')
```

CNTR2120
CNTR2130
CNTR2140
CNTR2150
CNTR2160
CNTR2170
CNTR2180
CNTR2190
CNTR2200
CNTR2210
CNTR2220
CNTR2230
CNTR2240
CNTR2250
CNTR2260
CNTR2270
CNTR2280
CNTR2290
CNTR2300
CNTR2310
CNTR2320
CNTR2330
CNTR2340
CNTR2350
CNTR2360
CNTR2370
CNTR2380
CNTR2390
CNTR2400
CNTR2410
CNTR2420
CNTR2430
CNTR2440
CNTR2450
CNTR2460
CNTR2470
CNTR2480
CNTR2490
CNTR2500
CNTR2510
CNTR2520
CNTR2530
CNTR2540
CNTR2550
CNTR2560
CNTR2570
CNTR2580
CNTR2590

```

71  WRITE(6,64)
64  FORMAT('0',T7,'NO GRAPH WILL BE PRODUCED.')
```

CNTR2120
CNTR2130
CNTR2140
CNTR2150
CNTR2160
CNTR2170
CNTR2180
CNTR2190
CNTR2200
CNTR2210
CNTR2220
CNTR2230
CNTR2240
CNTR2250
CNTR2260
CNTR2270
CNTR2280
CNTR2290
CNTR2300
CNTR2310
CNTR2320
CNTR2330
CNTR2340
CNTR2350
CNTR2360
CNTR2370
CNTR2380
CNTR2390
CNTR2400
CNTR2410
CNTR2420
CNTR2430
CNTR2440
CNTR2450
CNTR2460
CNTR2470
CNTR2480
CNTR2490
CNTR2500
CNTR2510
CNTR2520
CNTR2530
CNTR2540
CNTR2550
CNTR2560
CNTR2570
CNTR2580
CNTR2590

```

RETURN
CHECK IF IW IS TOO WIDE
2  IF(IW-9) 3,3,40
40  WRITE(6,61)
61  FORMAT('0',T7,'IW PARAMETER GREATER THAN 9. CNTUR WILL SET IW=9.')
```

CNTR2120
CNTR2130
CNTR2140
CNTR2150
CNTR2160
CNTR2170
CNTR2180
CNTR2190
CNTR2200
CNTR2210
CNTR2220
CNTR2230
CNTR2240
CNTR2250
CNTR2260
CNTR2270
CNTR2280
CNTR2290
CNTR2300
CNTR2310
CNTR2320
CNTR2330
CNTR2340
CNTR2350
CNTR2360
CNTR2370
CNTR2380
CNTR2390
CNTR2400
CNTR2410
CNTR2420
CNTR2430
CNTR2440
CNTR2450
CNTR2460
CNTR2470
CNTR2480
CNTR2490
CNTR2500
CNTR2510
CNTR2520
CNTR2530
CNTR2540
CNTR2550
CNTR2560
CNTR2570
CNTR2580
CNTR2590

```

1) IW=9
NOW CHECK IH PARAMETER
3  IF(IH) 4,4,5
4  WH ICH=HEIGHT
5  GO TO 1
DITSOX=(N-1.0)/IW
DITSXY=(-1.0+M)/IH
XMIN=1.0
YMIN=-M
SLOPEX=1.0/DITSOX
SLOPEY=1.0/DITSXY
DITSX(1)=1.0
DITSX(4)=1.0
DITSX(5)=1.0
DITSX(2)=N
DITSX(3)=N
DITSY(1)=-1.0
DITSY(2)=-1.0
DITSY(5)=-1.0
DITSY(3)=-M
DITSY(4)=-M
DO 2011 I=1,5
DITSX(I)=SLOPEX*(DITSX(1)-XMIN)
DITSY(I)=SLOPEY*(DITSY(1)-YMIN)
STARTP=(9.0-IW)/2.0
2011 CALL PLOTS
CALL PLOT(STARTP,0.0,-3)
CALL LINE(DITSX,DITSY,5,1,1)
DITSX(1)=DITSX(1)-.5
DITSX(5)=DITSX(1)
```

CNTR2120
CNTR2130
CNTR2140
CNTR2150
CNTR2160
CNTR2170
CNTR2180
CNTR2190
CNTR2200
CNTR2210
CNTR2220
CNTR2230
CNTR2240
CNTR2250
CNTR2260
CNTR2270
CNTR2280
CNTR2290
CNTR2300
CNTR2310
CNTR2320
CNTR2330
CNTR2340
CNTR2350
CNTR2360
CNTR2370
CNTR2380
CNTR2390
CNTR2400
CNTR2410
CNTR2420
CNTR2430
CNTR2440
CNTR2450
CNTR2460
CNTR2470
CNTR2480
CNTR2490
CNTR2500
CNTR2510
CNTR2520
CNTR2530
CNTR2540
CNTR2550
CNTR2560
CNTR2570
CNTR2580
CNTR2590


```

DITSX(4)=DITSX(4)-.5
DITSX(2)=DITSX(2)+.5
DITSX(3)=DITSX(3)+.5
DITSY(1)=DITSY(1)+.5
DITSY(5)=DITSY(1)
DITSY(2)=DITSY(2)+.5
DITSY(3)=DITSY(3)-.5
DITSY(4)=DITSY(4)-.5
CALL LINE(DITSX,DITSY,5,1,1)
SLOPEX=1.0/DITSX
SLOPEY=1.0/DITSY
IENDX=SLOPEX*M+1
IENDY=SLOPEY*M+1
IF(.NOT.LTG(2)) GO TO 34
DRAW TIC MARKS ON OUTER FRAME
START ON LEFT EDGE GOING DOWNWARD
IFLAG=0
ZINGX=-.1
ZINGY=0.0
ZX=0.0
ZY=-1.0
CX=DITSX(1)-.5
CY=DITSY(1)-.5
IEND=IENDY
IFLAG=IFLAG+1
DO 2022 I=1,IEND
CALL PLOT(CX,CY,3)
COORDX=CX+ZINGX
COORDY=CY+ZINGY
CALL PLOT(COORDX,COORDY,2)
CX=CX+ZX
CY=CY+ZY
GO TO (21,22,23,24),IFLAG
NCW DO THE RIGHT EDGE GOING DOWNWARD
2022 ZINGX=.1
CX=DITSX(2)
CY=DITSY(2)-.5
GO TO 2222
NCW DO TOP EDGE
22 ZINGX=0.0
ZINGY=.1
ZX=1.0
ZY=0.0
CX=DITSX(1)+.5
CY=DITSY(1)
IEND=IENDX
GO TO 2222
NCW DO THE BOTTOM EDGE

```

CNTR2600
 CNTR2610
 CNTR2620
 CNTR2630
 CNTR2640
 CNTR2650
 CNTR2660
 CNTR2670
 CNTR2680
 CNTR2690
 CNTR2700
 CNTR2710
 CNTR2720
 CNTR2730
 CNTR2740
 CNTR2750
 CNTR2760
 CNTR2770
 CNTR2780
 CNTR2790
 CNTR2800
 CNTR2810
 CNTR2820
 CNTR2830
 CNTR2840
 CNTR2850
 CNTR2860
 CNTR2870
 CNTR2880
 CNTR2890
 CNTR2900
 CNTR2910
 CNTR2920
 CNTR2930
 CNTR2940
 CNTR2950
 CNTR2960
 CNTR2970
 CNTR2980
 CNTR2990
 CNTR3000
 CNTR3010
 CNTR3020
 CNTR3030
 CNTR3040
 CNTR3050
 CNTR3060
 CNTR3070


```

23  ZINGY=-.1
    CX=DITSX(4)+.5
    CY=DITSY(4)
    ZINGY=-.1
    GO TO 222
    NOW LABEL TIC MARKS
    DO X-DIRECTION FIRST, TOP EDGE
    POSITION PEN
    DELTAX=DITSX
    24  IFLAG=0
    ZY=1.0
    ZY=0.0
    CX=DITSX(1)+.35
    CY=DITSY(1)+.12
    IFLAG=IFLAG+1
    3033  XZERO=1.0
    DO 3333 I=1, IEND
    CALL NUMBER(CX,CY,.07,XZERO,0.0,1)
    CX=CX+ZX
    CY=CY+ZY
    3333  XZERO=XZERO+DELTAX
    GO TO (31,32,33,34), IFLAG
    LABEL BOTTOM EDGE TIC MARKS
    31  CX=DITSX(4)+.35
    CY=DITSY(4)-.19
    GO TO 3033
    LABEL LEFT EDGE OF TIC MARKS
    32  CX=DITSX(4)-.4
    CY=DITSY(4)+.46
    DELTAX=DITSY
    IEND=IENDY
    ZY=0.0
    ZY=1.0
    GO TO 3033
    3033  RIGHT EDGE TIC MARKS
    NOW LABEL
    CX=DITSX(3)+.12
    CY=DITSY(3)+.46
    GO TO 3033
    CHECK IF GRID DESIRED
    34  IF(.NOT.LTG(3)) GO TO 35
    DRAW INCH BY INCH GRID
    IEND=IENDX-2
    POSITION PEN
    IFLAG=0
    CX=DITSX(1)+.5
    CY=DITSY(1)-.5
    COORDX=0.0
    COORDY=-IH

```

```

CNTR3080
CNTR3090
CNTR3100
CNTR3110
CNTR3120
CNTR3130
CNTR3140
CNTR3150
CNTR3160
CNTR3170
CNTR3180
CNTR3190
CNTR3200
CNTR3210
CNTR3220
CNTR3230
CNTR3240
CNTR3250
CNTR3260
CNTR3270
CNTR3280
CNTR3290
CNTR3300
CNTR3310
CNTR3320
CNTR3330
CNTR3340
CNTR3350
CNTR3360
CNTR3370
CNTR3380
CNTR3390
CNTR3400
CNTR3410
CNTR3420
CNTR3430
CNTR3440
CNTR3450
CNTR3460
CNTR3470
CNTR3480
CNTR3490
CNTR3500
CNTR3510
CNTR3520
CNTR3530
CNTR3540
CNTR3550

```



```

4044 DX=1.0
      DY=0.0
      DO 4444 I=1, IEND
      CX=CX+DX
      CY=CX+DY
      CALL PLOT(CX,CY,3)
      ZX=CX+COORDX
      ZY=CX+COORDY
4444 CALL PLOT(ZX,ZY,2)
      IF(IFLAG) 35,42,35
      IFLAG=1
      IEND=IENDY-2
      CY=DITSY(4)+.5
      CX=DITSX(4)+.5
      COORDX=IW
      COORDY=0.0
      DX=0.0
      DY=1.0
      GO TO 4044
35 CONTINUE
      NLEV=NL
      CHECK IF CONTUR IS TO COMPUTE LEVELS
      IF(NLEV) 6,7,11
      NL NEGATIVE MEANS CONTOUR MUST COMPUTE LEVELS
      SCAN MATRIX FOR LOWEST AND HIGHEST LEVELS
      NLEV=-NLEV
      FMIN=AM(1,1)
      FMAX=FMIN
      DO 9 I=1,M
      DO 9 J=1,N
      IF(AM(I,J).LT.FMIN) FMIN=AM(I,J)
      IF(AM(I,J).GT.FMAX) FMAX=AM(I,J)
      CONTINUE
      CHECK IF MIN AND MAX ARE EQUAL
      IF(FMIN.EQ.FMAX) GO TO 300
      DELTAL=(FMAX-FMIN)/(NLEV-1)
      SET UP CL ARRAY
      DO 10 I=1,NLEV
      CL(I)=FMIN+(I-1)*DELTAL
      DO 20 I=1,NLEV
      CALL SCAN(AM,M,N,MX,CL(I))
      IF(.NOT.LABL) GO TO 778
      IF(JC.EQ.0) GO TO 778
      DO 777 I=1,JC
      COORDX=TABC(I,4)
      COORDY=TABC(I,5)
      CLEV=TABC(I,6)
      CALL NUMBER(COORDX,COORDY,.07,CLEV,0.0,1)

```

CNTR3560
 CNTR3570
 CNTR3580
 CNTR3590
 CNTR3600
 CNTR3610
 CNTR3620
 CNTR3630
 CNTR3640
 CNTR3650
 CNTR3660
 CNTR3670
 CNTR3680
 CNTR3690
 CNTR3700
 CNTR3710
 CNTR3720
 CNTR3730
 CNTR3740
 CNTR3750
 CNTR3760
 CNTR3770
 CNTR3780
 CNTR3790
 CNTR3800
 CNTR3810
 CNTR3820
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 CNTR3850
 CNTR3860
 CNTR3870
 CNTR3880
 CNTR3890
 CNTR3900
 CNTR3910
 CNTR3920
 CNTR3930
 CNTR3940
 CNTR3950
 CNTR3960
 CNTR3970
 CNTR3980
 CNTR3990
 CNTR4000
 CNTR4010
 CNTR4020
 CNTR4030

CNTR4040
CNTR4050
CNTR4060
CNTR4070
CNTR4080
CNTR4090
CNTR4100
CNTR4110
CNTR4120
CNTR4130
CNTR4140
CNTR4150
CNTR4160

```

777 CONTINUE
778 CALL SYMBOL(-STARTP,IH+1.0,.21,TITLE(7),0.0,48)
    CALL SYMBOL(-STARTP,IH+1.5,.21,TITLE(1),0.0,48)
    CALL PLOCT(-STARTP,IH+5.0,-3)
    CALL PLOTE
    RETURN
300 WRITE(6,62) FMIN
62  FORMAT('0',T7,'DATA MATRIX HAS ONLY ONE LEVEL=',E15.3)
    GO TO 71
7  WRITE(6,63)
63  FORMAT('0',T7,'NUMBER OF LEVELS REQUESTED=0.')
```

CNTR4170
CNTR4180
CNTR4190
CNTR4200
CNTR4210
CNTR4220
CNTR4230
CNTR4240
CNTR4250
CNTR4260
CNTR4270
CNTR4280
CNTR4290
CNTR4300
CNTR4310
CNTR4320
CNTR4330
CNTR4340
CNTR4350
CNTR4360
CNTR4370
CNTR4380
CNTR4390
CNTR4400
CNTR4410
CNTR4420
CNTR4430
CNTR4440
CNTR4450
CNTR4460
CNTR4470
CNTR4480
CNTR4490

```

THIS SUBROUTINE SCAN(AM,M,N,MX,CL)
      PROGRAM IS WRITTEN BY M.O.DAYHOFF
      DIMENSION AM(MX,1),REC(900), X(1800), Y(1800)
      DIMENSION IPT(3,3),INX(8),INY(8)
      COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,NQ,JT,
1      PY,REC,CV, IPT,INX,INY,DL,RA,THE
      COMMON /INTFAC/ X,Y
      LOGICAL *1 LABL,MINUS
      CCOMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITS DX,DITS DY,DIR,LABL,MINUS
      D=0.
      R=1.
      TH = 1.570796
      NP=0
      DL=D
      RA=R
      TFE=TH
      MT=N
      NT=M
      CV=CL
      IF(IZW-120631) 1,3,1
1      IPT(1,1)=8
        IPT(1,2)=1
        IPT(1,3)=2
        IPT(2,1)=7
        IPT(2,3)=3
        IPT(3,1)=6
        IPT(3,2)=5
        IPT(3,3)=4
        INX(1)=-1
        INX(2)=-1
        INX(3)=0
        INX(4)=1
        INX(5)=1
```



```

INX(6)=1
INX(7)=0
INX(8)=-1
INY(1)=0
INY(2)=1
INY(3)=+1
INY(4)=+1
INY(5)=0
INY(6)=-1
INY(7)=-1
INY(8)=-1
IZW=120631
3  XT=MT
58  DO 58 J=1,900
58  REC(J)=0
2  MT=MT-1
2  DIR=1
DO 110 I=1,MT1
55  IF(AM(I,I)-CV) 55,110,110
57  IF(AM(I,I+1)-CV) 110,57,57
57  IX=I+1
57  IY=I
57  IDX=-1
57  IDY=0
CALL TRACE (AM,MX)
110 CONTINUE
NT1=NT-1
DIR=2
DO 20 I=1,NT1
15  IF(AM(I,MT)-CV) 15,20,20
17  IF(AM(I+1,MT)-CV) 20,17,17
17  IX=MT
17  IY=I+1
17  IDX=0
17  IDY=-1
CALL TRACE (AM,MX)
20 CONTINUE
DIR=3
DO 22 MT=MT+1-I
22  IF(AM(MT,MT2)-CV) 25,30,30
25  IF(AM(MT,MT2-1)-CV) 30,27,27
27  IX=MT2-1
27  IY=NT
27  IDX=1
27  IDY=0
CALL TRACE (AM,MX)

```

```

CNTR4500
CNTR4510
CNTR4520
CNTR4530
CNTR4540
CNTR4550
CNTR4560
CNTR4570
CNTR4580
CNTR4590
CNTR4600
CNTR4610
CNTR4620
CNTR4630
CNTR4640
CNTR4650
CNTR4660
CNTR4670
CNTR4680
CNTR4690
CNTR4700
CNTR4710
CNTR4720
CNTR4730
CNTR4740
CNTR4750
CNTR4760
CNTR4770
CNTR4780
CNTR4790
CNTR4800
CNTR4810
CNTR4820
CNTR4830
CNTR4840
CNTR4850
CNTR4860
CNTR4870
CNTR4880
CNTR4890
CNTR4900
CNTR4910
CNTR4920
CNTR4930
CNTR4940
CNTR4950
CNTR4960
CNTR4970

```



```

30 CCNTINUE
   IDIR=4
   DO 40 I=1,NT1
      NT2=NT+1-I
      IF (AM(NT2,1)-CV) 35,40,40
35   IF (AM(NT2-1,1)-CV) 40,37,37
37   IX=1
      IY=NT2-1
      IDX=0
      IDY=1
      CALL TRACE (AM,MX)
40   CCNTINUE
      IDIR=5
      ISS=1
      NT1=NT-1
      MT1=MT-1
      DO 10 J=2,NT1
         DC 10 I=1,MT1
         IF (AM(J,I}-CV) 5,10,10
5       IF (AM(J,I+1)-CV) 10,7,7
7       CGM=100*(I+1)+J
         IF (NP) 12,11,12
12      DC 9 ID=1,NP
          IF (REC(ID)-COM) 9,10,9
9        CCNTINUE
11      IX= I+1
          IY=J
          IDX=-1
          IDY=0
          CALL TRACE (AM,MX)
10      CCNTINUE
          RETURN
          END

```

```

SUBROUTINE TRACE (AM,MY)
  DIMENSION AM(MY,1),REC(900), X(1800), Y(1800)
  DIMENSION IPT(3,3), INX(8), INY(8)
  COMMON /DAYHOF/ MT,NT,IX,IY,IDX,IDY,ISS,IT,IV,NP,N,JT,
1    PY,REC,CV,
  COMMON /INTFAC/ X,Y
  PY=0.0
  RC= COS (THE)*RA
  RS= SIN (THE)*RA
501  JT=0
      N=0
      IXC=IX
      IYO=IY

```

CNTR4980
 CNTR4990
 CNTR5000
 CNTR5010
 CNTR5020
 CNTR5030
 CNTR5040
 CNTR5050
 CNTR5060
 CNTR5070
 CNTR5080
 CNTR5090
 CNTR5100
 CNTR5110
 CNTR5120
 CNTR5130
 CNTR5140
 CNTR5150
 CNTR5160
 CNTR5170
 CNTR5180
 CNTR5190
 CNTR5200
 CNTR5210
 CNTR5220
 CNTR5230
 CNTR5240
 CNTR5250
 CNTR5260
 CNTR5270
 CNTR5280
 CNTR5290
 CNTR5300

CNTR5310
 CNTR5320
 CNTR5330
 CNTR5340
 CNTR5350
 CNTR5360
 CNTR5370
 CNTR5380
 CNTR5390
 CNTR5400
 CNTR5410
 CNTR5420
 CNTR5430

CNTR5440
CNTR5450
CNTR5460
CNTR5470
CNTR5480
CNTR5490
CNTR5500
CNTR5510
CNTR5520
CNTR5530
CNTR5540
CNTR5550
CNTR5560
CNTR5570
CNTR5580
CNTR5590
CNTR5600
CNTR5610
CNTR5620
CNTR5630
CNTR5640
CNTR5650
CNTR5660
CNTR5670
CNTR5680
CNTR5690
CNTR5700
CNTR5710
CNTR5720
CNTR5730
CNTR5740
CNTR5750
CNTR5760
CNTR5770
CNTR5780
CNTR5790
CNTR5800
CNTR5810
CNTR5820
CNTR5830
CNTR5840
CNTR5850
CNTR5860
CNTR5870
CNTR5880
CNTR5890
CNTR5900
CNTR5910

```

ISX=IDX+2
ISY=IDY+2
IS=IPT(ISX,ISY)
JTB=0
ISO=IS
IF(ISO-8)18,18,17
ISO=ISO-8
IT=0
CONTINUE
CALL CALC (AM,MY)
NZ=N
N=NZ
IF (IT+JT-1) 49,49,47
47 XS=X(N-1)
YS=Y(N-1)
X(N-1)=X(N)
Y(N-1)=Y(N)
X(N)=XS
Y(N)=YS
IS=IS+1
49 JT=IT
IF (IS-9) 8,7,7
9 IS=IS-8
7 IDX=INX(IS)
8 IDY=INY(IS)
IX2=IX+IDX
IY2=IY+IDY
JTB=JTB+1
IF (JTB-1799) 51,51,308
308 PRINT
103 FORMAT(1H0,23HA CONTOUR LINE AT LEVEL,E12.5,21H WAS TERMINATED AT
1X=E12.5,3H Y=E12.5/
2 48H BECAUSE IT CONTAINED MORE THAN 1799 PLCT POINTS )
2 RETURN

SHOULD TEST HERE FOR MAXIMUM NUMBER OF PLOTTABLE POINTS IN SEGMENT.
51 CONTINUE
IF (ISS) 10,10,20
20 IF (IX-IX0) 12,21,12
21 IF (IY-IY0) 12,22,12
22 IF (IS-ISO) 12,23,12
23 CONTINUE
CALL CALC (AM,MY)
GC TO 73
10 IF (IX2) 13,50,13
13 IF (IX2-MT) 19,19,50
19 IF (IY2) 11,50,11
11 IF (IY2-MT) 12,12,50

```


CNTR5920
CNTR5930
CNTR5940
CNTR5950
CNTR5960
CNTR5970
CNTR5980
CNTR5990
CNTR6000
CNTR6010
CNTR6020
CNTR6030
CNTR6040
CNTR6050
CNTR6060
CNTR6070
CNTR6080
CNTR6090
CNTR6100
CNTR6110
CNTR6120
CNTR6130
CNTR6140
CNTR6150
CNTR6160
CNTR6170
CNTR6180
CNTR6190
CNTR6200
CNTR6210
CNTR6220
CNTR6230
CNTR6240

CNTR6250
CNTR6260
CNTR6270
CNTR6280
CNTR6290
CNTR6300
CNTR6310
CNTR6320
CNTR6330
CNTR6340
CNTR6350
CNTR6360
CNTR6370

```

12 IF (CV-AM( IY2, IX2)) 206,206,5
206 IF ( IY2**2+IDY**2-1) 213,6,213
213 DCP=(AM( IY, IX)+AM( IY, IX2)+AM( IY2, IX)+AM( IY2, IX2))/4.0
217 IF ( DCP-CV) 5,217,217
214 IF ( INX( IS-1)) 214,215,214
      IX=IX+IDY
      IDY=-IDY
      PY=2.0
      CALL CALC (AM,MY)
      IX=IX+IDY
      GO TO 6
215 IY=IY+IDY
      IDY=-IDY
      PY=2.0
      CALL CALC (AM,MY)
      IY=IY+IDY
      IF (AM( IY, IX-1)-CV) 306,16,16
306 NP=NP+1
16 REC(NP)=100*IX+IY
      IS=IS+5
      IX=IX2
      IY=IY2
      GO TO 9
50 XT=MT
      IF (AM( IY, IX-1)-CV) 307,73,73
307 NP=NP+1
73 REC(NP)=100*IX+IY
      DO 74 I=1,N
74 X(I)=X(I)+RC*Y(I)
      Y(I)=RS*Y(I)
      CALL PLOTT(N,CV)
      RETURN
      END

```

```

SUBROUTINE CALC(AM,MY)
DIMENSION AM(MY,1),REC(900), X(1800), Y(1800)
DIMENSION IPT(3,3),INX(8),INY(8)
COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N ,JT,
1 PY,REC,CV,
      COMMON /INTFAC/ X,Y
      IT=0
      N=NT+1
      IF ( IY2**2 + IDY**2 -1) 20,1,20
1 IF ( IY2) 10,2,10
2 X(N)=IX
  Z=IY
  IY2=IY+IDY

```



```

41 DY=IDY
   Y(N)=((AM(IY,IX)-CV)/(AM(IY,IX)-AM(IY2,IX)))*DY+Z
10 RETURN
   Y(N)=IY
   W=IX
   CX=IDX
   IX2=IX+IDX
44 X(N)=((AM(IY,IX)-CV)/(AM(IY,IX)-AM(IY,IX2)))*DX+W
20 RETURN
   IX2=IX+IDX
   IY2=IY+IDY
   W=IX
   Z=IY
   CX=IDX
   DY=IDY
   DCP=(AM(IY,IX)+AM(IY,IX2)+AM(IY2,IX)+AM(IY2,IX2))/4.0
   IF (PY-2.0) 24,21,24
24 IF (DCP-CV) 21,21,25
21 AL=AM(IY,IX)-DCP
23 V=.5*(AL+DCP -CV)/AL
27 X(N)=V*DX+W
   Y(N)=V*DY+Z
   PY=0.0
   RETURN
25 IT=1
   AL=AM(IY2,IX2)-DCP
33 V=.5*(AL+DCP-CV)/AL
28 X(N)=-V*DX+W + DX
   Y(N)=-V*DY+Z + DY
   RETURN
   END

```

CNTR6380
 CNTR6390
 CNTR6400
 CNTR6410
 CNTR6420
 CNTR6430
 CNTR6440
 CNTR6450
 CNTR6460
 CNTR6470
 CNTR6480
 CNTR6490
 CNTR6500
 CNTR6510
 CNTR6520
 CNTR6530
 CNTR6540
 CNTR6550
 CNTR6560
 CNTR6570
 CNTR6580
 CNTR6590
 CNTR6600
 CNTR6610
 CNTR6620
 CNTR6630
 CNTR6640
 CNTR6650
 CNTR6660
 CNTR6670
 CNTR6680
 CNTR6690

```

SUBROUTINE PLOTT(NP,CV)
COMMON/INTFAC/X(1800),Y(1800)
LOGICAL AL#1,MINUS,LABL
COMMON/TABL/ TABC(20,6),JC
COMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITS DX,DITS DY,MINUS
SCALE PCINTS FOR PLOT ROUTINE
DC 100 I=1,NP
X(I)=SLOPEX*(X(I)-XMIN)
100 Y(I)=SLOPEY*(-Y(I)-YMIN)
   CALL LINE(X,Y,NP,1,1)
   IF(.NOT.LABL) RETURN
   SHOULD ADJUSTMENT CF PEN LOCATION BE MADE FOR LABELLING CURVE?
   DIR=0.0
   GC TO (1,2,3,4,6), IDIR

```

CNTR6700
 CNTR6710
 CNTR6720
 CNTR6730
 CNTR6740
 CNTR6750
 CNTR6760
 CNTR6770
 CNTR6780
 CNTR6790
 CNTR6800
 CNTR6810
 CNTR6820
 CNTR6830


```

1 DIR=90.
2 CCORDX=X(1)
3 CCORDY=Y(1)
5 CALL NUMBER(COORDX,COORDY,.07,CV,DIR,1)
RETURN
MOVE PEN DOWN ONE HALF INCH
3 DIR=90.
CCORDX=X(1)
CCORDY=Y(1) -.3
GO TO 5
MOVE PEN TO THE LEFT
4 CCORDX=X(1) -.3
CCORDY=Y(1)
GO TO 5
SEARCH FOR XMAX,XMIN,YMAX,YMIN,AND SAVE YMINX
6 XMAX=X(1)
SMIN=XMAX
YMINX=Y(1)
YMAX=YMINX
VMIN=YMINX
DO 200 I=2,NP
IF(X(I).GT.XMAX) XMAX=X(I)
IF(Y(I).LT.VMIN) VMIN=Y(I)
IF(Y(I).GT.YMAX) YMAX=Y(I)
IF(X(I).GE.SMIN) GO TO 200
SMIN=X(I)
YMINX=Y(I)
CCONTINUE
200 JC=NUMBER OF ENTRIES IN TABC
IF(JC) 400,500,400
SEARCH TABLE TO SEE IF THIS IS INTERIOR TC ANOTHER INTERIOR SEGMENT
400 DO 900 I=1,JC
IF(XMAX.LT.TABC(I,1).AND.YMAX.LT.TABC(I,2).AND.VMIN.GT.TABC(I,3).
AND.SMIN.GT.TABC(I,4)) GO TO 700
1 CCNTINUE
DID NOT FIND THIS CONTOUR TO BE INTERIOR TC ANOTHER
CHECK IF EXTERIOR
DO 1000 I=1,JC
IF(XMAX.GT.TABC(I,1).AND.YMAX.GT.TABC(I,2).AND.VMIN.LT.TABC(I,3).
AND.SMIN.LT.TABC(I,4)) GO TO 800
1 CCNTINUE
THIS CONTOUR SEGMENT WAS NEITHER INTERIOR NCR EXTERIOR TC ANOTHER
500 IF (JC.EQ.20) RETURN
JC=JC+1
MC=JC
TABC(MC,1)=XMAX
TABC(MC,2)=YMAX
TABC(MC,3)=VMIN
600

```

CNTR6840
 CNTR6850
 CNTR6860
 CNTR6870
 CNTR6880
 CNTR6890
 CNTR6900
 CNTR6910
 CNTR6920
 CNTR6930
 CNTR6940
 CNTR6950
 CNTR6960
 CNTR6970
 CNTR6980
 CNTR6990
 CNTR7000
 CNTR7010
 CNTR7020
 CNTR7030
 CNTR7040
 CNTR7050
 CNTR7060
 CNTR7070
 CNTR7080
 CNTR7090
 CNTR7100
 CNTR7110
 CNTR7120
 CNTR7130
 CNTR7140
 CNTR7150
 CNTR7160
 CNTR7170
 CNTR7180
 CNTR7190
 CNTR7200
 CNTR7210
 CNTR7220
 CNTR7230
 CNTR7240
 CNTR7250
 CNTR7260
 CNTR7270
 CNTR7280
 CNTR7290
 CNTR7300
 CNTR7310


```

TABC(MC,4)=SMIN
TABC(MC,5)=YMINX
TABC(MC,6)=CV
RETURN
CHECK IF THIS INTERIOR ONE IS OF HIGHER LEVEL
700 IF(CV.LE.TABC(I,6)) RETURN
2000 MC=I
GO TO 600
CHECK IF LEVEL OF THIS EXTERIOR ONE IS HIGHER
800 IF(CV.LT.TABC(I,6)) RETURN
GO TO 2000
END

```

```

CNTR7320
CNTR7330
CNTR7340
CNTR7350
CNTR7360
CNTR7370
CNTR7380
CNTR7390
CNTR7400
CNTR7410
CNTR7420
CNTR7430

```


SUBPROGRAMS
AND RELATED SUBROUTINES

79


```

10 READ(5,103,END=10)(BB(I,J),I=1,NP)
11 CONTINUE
12 DC 110 J=1,NT
13 LW1=LW+1
14 X(1)=RMAX+(L2-1)*DR
15 X(2)=-RMAX+(L2+N)*DR
16 Y(1)=BB(L2,J)
17 Y(2)=BB(LW1,J)
18 DC 20 I=1,N
19 U(I)=-RMAX+(L2-1+I)*DR
20 CONTINUE
21 WRITE(6,103)X(1),X(2)
22 WRITE(6,103)Y(1),Y(2)
23 WRITE(6,103)(U(I),I=1,N)
24 CALL INTRPL(N2N,X,Y,N,U,V)
25 WRITE(6,103)(V(I),I=1,N)
26 TO PRINT THE OUTPUT (I.E. Y(1) TO Y(36), V(1), TO V(25),
27 *** IN A TOTAL 8F10.5 FORMAT, STORE THE
28 *** TWO VECTORS IN BB(I,J)
29 DC 30 I=1,N
30 KB=L2+1
31 BB(KB,J)=V(I)
32 CONTINUE
33 WRITE(6,103) TH(J)
34 WRITE(6,103)(BB(I,J),I=1,NP)
35 WRITE(7,103) TH(J)
36 WRITE(7,103)(BB(I,J),I=1,NP)
37 CONTINUE
38 STOP
39 END

```

.....

INTR0010
INTR0020

SUBROUTINE INTRPL (CATEGORY E2)

1. IDENTIFICATION:

A. NAME: INTERPOLATION OF A SINGLE VALUED FUNCTION
BASED ON LOCAL PROCEDURES

B. PROGRAMMER: HIROSHI AKIMA

INTR0030
INTR0040
INTR0050
INTR0060
INTR0070
INTR0080
INTR0090
INTR0100

C. IMPLEMENTER: MICHAEL CORCORAN

D. DATE: MARCH, 1973

2. PURPOSE:

A. THE INTRPL SUBROUTINE INTERPOLATES, FROM VALUES OF THE

FUNCTION GIVEN AS ORDINATES OF INPUT DATA POINTS IN AN
X-Y PLANE AND FOR A GIVEN SET OF X VALUES (ABSCISSAS OF
DESIRED POINTS), THE VALUES OF A SINGLE VALUED FUNCTION
Y = Y(X).

3. USAGE:

A. CALLING STATEMENT:

CALL INTRPL(L,X,Y,N,U,V)

WHERE THE INPUT PARAMETERS ARE:

- 1) L - THE NUMBER OF INPUT DATA POINTS (MUST BE 2 OR MORE)
- 2) X - AN ARRAY OF DIMENSION L STORING THE X VALUES
(ABSCISSAS) OF THE INPUT DATA POINTS IN ASCENDING
ORDER....X(I+1) > X(I) (TYPE REAL*4)
- 3) Y - AN ARRAY OF DIMENSION L STORING THE Y VALUES
(ORDINATES) OF THE INPUT DATA POINTS (TYPE REAL*4)
- 4) N - THE NUMBER OF POINTS AT WHICH INTERPOLATION OF THE
Y VALUE (ORDINATE) IS DESIRED (MUST BE ONE OR MORE)
- 5) U - THE ARRAY OF DIMENSION N STORING THE X VALUES
(ABSCISSAS) OF DESIRED POINTS (TYPE REAL*4)

AND WHERE THE OUTPUT PARAMETER IS

- 6) V - THE ARRAY OF DIMENSION N WHERE THE INTERPOLATED
Y VALUES (ORDINATES) ARE TO BE PLACED

B. ERROR MESSAGES:

- 1) *** L = 1 OR LESS. N = (I7)
L = (I7)

INTR0110
INTR0120
INTR0130
INTR0140
INTR0150
INTR0160
INTR0170
INTR0180

INTR0190
INTR0200
INTR0210
INTR0220
INTR0230
INTR0240
INTR0250
INTR0260
INTR0270
INTR0280
INTR0290
INTR0300
INTR0310
INTR0320
INTR0330
INTR0340
INTR0350
INTR0360
INTR0370
INTR0380
INTR0390
INTR0400
INTR0410
INTR0420
INTR0430
INTR0440
INTR0450
INTR0460
INTR0470
INTR0480
INTR0490
INTR0500
INTR0510
INTR0520
INTR0530
INTR0540
INTR0550
INTR0560

ERROR DETECTED IN ROUTINE INTRPL" (THE APPROPRIATE
VALUES ARE PRINTED WHERE FORMATS ARE INDICATED)

- 2) *** N = 0 OR LESS.
L = (I7)
ERROR DETECTED IN ROUTINE INTRPL"
- 3) *** IDENTICAL X VALUES.
I = (I7) X(I) = (E12.3)
L = (I7) N = (I7)
ERROR DETECTED IN ROUTINE INTRPL" (THE VALUES IN
THE X ARRAY MUST BE IN STRICT ASCENDING SEQUENCE.)
- 4) *** X VALUES OUT OF SEQUENCE.
I = (I7) X(I) = (E12.3)
L = (I7) I = (I7)
ERROR DETECTED IN ROUTINE INTRPL" (X(I) < X(I-1) FOR
SOME I BETWEEN
2 AND L.)

4. MODE OF ARITHMETIC:

SINGLE PRECISION

5. REMARKS:

A. WHEN THE FUNCTION TO BE INTERPOLATED REPRESENTS A PERIODIC

FUNCTION AND A SET OF L DATA POINTS CCVERS A WHOLE PERIOD,
TWO ADDITIONAL DATA POINTS SHCULD BE ADDED AT EACH END AND
A SET OF L+4 DATA POINTS SHOULD BE GIVEN AS THE INPUT DATA
POINTS TO THIS SUBROUTINE.

B. CORE REQUIREMENT FOR INTRPL: 2968 BYTES.

C. NO SUBROUTINES OR FUNCTION SUBPROGRAMS ARE REQUIRED.

D. FOR THE CONVENIENCE OF THE NPS USER, THE ORIGINAL FORTRAN
PROGRAM WAS MODIFIED SLIGHTLY. AN UNNECESSARY INPUT
PARAMETER - IU, WHICH DESIGNATED THE CUPUT DEVICE NUMBER
FOR ERROR MESSAGES FROM INTRPL, WAS ELIMINATED FROM THE
PARAMETER LIST, AND THE FORTRAN CODE WAS MODIFIED TO CHANNEL
ALL ERROR MESSAGES TO THE LINE PRINTER AUTOMATICALLY.

6. METHOD:

THIS ROUTINE IS DEvised IN SUCH A WAY THAT A CURVE DWAWN

INTR0570
INTR0580
INTR0590
INTR0600
INTR0610
INTR0620
INTR0630
INTR0640
INTR0650
INTR0660
INTR0670
INTR0680
INTR0690
INTR0700
INTR0710
INTR0720
INTR0730
INTR0740
INTR0750
INTR0760
INTR0770
INTR0780
INTR0790
INTR0800
INTR0810
INTR0820
INTR0830

INTR0840
INTR0850
INTR0860
INTR0870
INTR0880
INTR0890
INTR0900
INTR0910
INTR0920
INTR0930
INTR0940
INTR0950
INTR0960
INTR0970
INTR0980
INTR0990
INTR1000
INTR1010
INTR1020

THROUGH BOTH THE GIVEN AND INTERPOLATED POINTS WILL APPEAR
SMOOTH AND NATURAL, FREE OF UNNATURAL WIGGLES. IT IS BASED
ON A PIECEWISE FUNCTION COMPOSED OF A SET OF POLYNOMIALS, ONE
EACH OF DEGREE THREE, AT MOST, AND APPLICABLE TO SUCCESSIVE
INTERVALS OF THE GIVEN AT POINTS. IN THIS METHOD, THE SLOPE OF
THE CURVE IS DETERMINED AT EACH GIVEN POINT LOCALLY, AND
EACH POLYNOMIAL REPRESENTING A PORTION OF THE CURVE, BETWEEN
A PAIR OF GIVEN POINTS IS DETERMINED BY THE COORDINATES OF
AND THE SLOPES AT THE POINTS. COMPARISON INDICATES THAT THE
CURVE OBTAINED BY THIS METHOD IS CLOSER TO A MANUALLY DRAWN
CURVE THAN THOSE DRAWN BY OTHER MATHEMATICAL METHODS...

A DETAILED EXPLANATION OF THE METHOD CAN BE FOUND IN THE
OCTOBER 1970 ISSUE, JOURNAL OF THE ACM, PAGE 589, ENTITLED:
"A NEW METHOD OF INTERPOLATION AND SMOOTH CURVE FITTING
BASED ON LOCAL PROCEDURES", BY HIROSHI AKIMA.

A DESCRIPTION OF THE ALGORITHM USED PLUS THE ORIGINAL
FORTRAN PROGRAM IS GIVEN IN THE OCTOBER 1972 ISSUE,
COMMUNICATIONS OF THE ACM, PAGE 914, ENTITLED:
"INTERPOLATION AND SMOOTH CURVE FITTING BASED ON LOCAL
PROCEDURES", BY HIROSHI AKIMA.

SUBROUTINE INTRPL(L,X,Y,N,U,V)
INTERPOLATION OF A SINGLE-VALUED FUNCTION OF THE FUNCTION
THIS SUBROUTINE INTERPOLATES, DATA POINTS IN AN X-Y PLANE
GIVEN AS ORDINATES OF INPUT DATA POINTS
AND FOR A GIVEN SET OF X VALUES (ABSCISSAS), THE VALUES OF
A SINGLE-VALUED FUNCTION $Y = Y(X)$.
THE INPUT PARAMETERS ARE
L = NUMBER OF INPUT DATA POINTS
X = (MUST BE 2 OR GREATER)
Y = ARRAY OF DIMENSION L STORING THE X VALUES
(ABSCISSAS) OF INPUT DATA POINTS
(IN ASCENDING ORDER)
N = ARRAY OF DIMENSION L STORING THE Y VALUES
(ORDINATES) OF INPUT DATA POINTS
U = NUMBER OF POINTS AT WHICH INTERPOLATION OF THE
Y VALUE (ORDINATE) IS DESIRED
(MUST BE 1 OR GREATER)
V = ARRAY OF DIMENSION N STORING THE X VALUES

INTR1030
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INTR1050
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INTR1070
INTR1080
INTR1090
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INTR1190
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      (ABSCISSAS) OF DESIRED POINTS
THE OUTPUT PARAMETER IS
V = ARRAY OF DIMENSION N WHERE THE INTERPOLATED Y
VALUES (ORDINATES) ARE TO BE DISPLAYED
DECLARATION STATEMENTS
DIMENSION X(L),Y(L),U(N),V(N)
EQUIVALENCE (P0,X3),(Q0,Y3),(Q1,T3)
REAL M1,M2,M3,M4,M5
EQUIVALENCE (UK,DX),(IMN,X2,A1,M1),(IMX,X5,A5,M5),
1 (J,SW,SA),(Y2,W2,W4,Q2),(Y5,W3,Q3)
PRELIMINARY PROCESSING
10 LO=L
LM1=LO-1
LM2=LM1-1
LPI=LO+1
NO=N
IF(LM2.LT.0) GO TO 90
IF(NO.LE.0) GO TO 91
DO 11 I=2,LO
IF(X(I-1)-X(I)) 11,95,96
11 CONTINUE
IPV=0
MAIN DC-LOOP K=1,NO
DC 80 K=U(K)
ROUTINE TO LOCATE THE DESIRED POINT
20 IF(LM2.EQ.0) GO TO 27
IF(UK.GE.X(LO)) GO TO 26
IF(UK.LT.X(1)) GO TO 25
IMN=2
IMX=LO
I=((IMN+IMX)/2)
IF(UK.GE.X(I)) GO TO 23
IMX=I
GO TO 24
IMN=I+1
IF(IMX.GT.IMN) GO TO 21
I=IMX
GO TO 30
I=1
GO TO 30
I=LPI
GO TO 30
I=2
GO TO 30
27 IF I = IPV
CHECK IF(I.EQ.IPV) GO TO 70
30 IPV=I
ROUTINES TO PICK UP NECESSARY X AND Y VALUES AND

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INTR1500
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INTR1950
INTR1960

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40      TO ESTIMATE THEM IF NECESSARY
      J=1
      IF(J.EQ.1)
      IF(J.EQ.LP1)
      J=2
      J=L0
      X3=X(J-1)
      Y3=Y(J-1)
      X4=X(J)
      Y4=Y(J)
      A3=X4-X3
      M3=(Y4-Y3)/A3
      IF(LM2.EQ.0)
      IF(J.EQ.2)
      X2=X(J-2)
      Y2=Y(J-2)
      A2=X3-X2
      M2=(Y3-Y2)/A2
      IF(J.EQ.L0)
      X5=X(J+1)
      Y5=Y(J+1)
      A4=X5-X4
      M4=(Y5-Y4)/A4
      IF(J.EQ.2)
      GO TO 45
      M4=M3+M3-M2
      GO TO 45
      M2=M3
      M4=M3
      IF(J.LE.3)
      A1=X2-X(J-3)
      M1=(Y2-Y(J-3))/A1
      GO TO 47
      M1=M2+M2-M3
      IF(J.GE.LM1)
      A5=X(J+2)-X5
      M5=(Y(J+2)-Y5)/A5
      GO TO 50
      M5=M4+M4-M3
      NUMERICAL DIFFERENTIATION
      IF(I.EQ.LP1)
      W2=ABS(M4-M3)
      W3=ABS(M2-M1)
      SW=W2+W3
      IF(SW.NE.0.0)
      W2=0.5
      W3=0.5
      SW=1.0
      T3=(W2*M2+W3*M3)/SW
      IF(I.EQ.1)
      GO TO 54

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INTR1990
INTR2000
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INTR2020
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INTR2120
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52  W3=ABS(M5-M4)
    W4=ABS(M3-M2)
    SW=W3+W4
    IF(SW.NE.0.0) GO TO 53
    W3=0.5
    W4=0.5
    SW=1.0
    T4=(W3*M3+W4*M4)/SW
    IF(I.NE.LPI) GO TO 60
    T3=T4
    SA=A2+A3
    T4=0.5*(M4+M5-A2*(A2-A3)*(M2-M3)/(SA*SA))
    X3=X4
    Y3=Y4
    A3=A2
    M3=M4
    GO TO 60
54  T4=T3
    SA=A3+A4
    T3=0.5*(M1+M2-A4*(A3-A4)*(M3-M4)/(SA*SA))
    X3=X3-A4
    Y3=Y3-M2*A4
    A3=A4
    M3=M2
    DETERMINATION OF THE COEFFICIENTS
60  Q2=(2.0*(M3-T3)+M3-T4)/A3
    Q3=(-M3-M3+T3+T4)/(A3*A3)
    COMPUTATION OF THE POLYNOMIAL
70  DX=UK-P0
80  V(K)=Q0+DX*(Q1+DX*(Q2+DX*Q3))
    RETURN
    ERROR EXIT (6,2090)
90  WRITE TO 99
91  WRITE (6,2091)
95  WRITE TO 99
95  WRITE (6,2095)
96  GO TO 97
96  WRITE (6,2096)
97  WRITE (6,2097)
99  WRITE (6,2099)
    RETURN
    I,X(I)
    LO,NO
    *** L = 1 OR LESS.//
    *** N = 0 OR LESS.//
    *** IDENTICAL X VALUES.//
    *** X VALUES OUT OF SEQUENCE.//
    I = , I7, 10X, 6HX(I) = , E12.3)
2090  FORMAT(1X/22H
2091  FORMAT(1X/22H
2095  FORMAT(1X/27H
2096  FORMAT(1X/33H
2097  FORMAT(6H

```


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13. ABSTRACT

Fiber light guides are used in conjunction with holographic interferometry. A Michelson interferometer was constructed to test for temporal coherence of light passing through fiber optics. A finite-fringe hologram of a no-flow condition was taken to prove the feasibility of applying fiber optics to this field of flow investigation.

The effect of opaque bodies on interferometric data inversion was sought. Two schemes for replacing the missing fringe data were used to see if the accuracy of the calculated density fields could be enhanced.

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